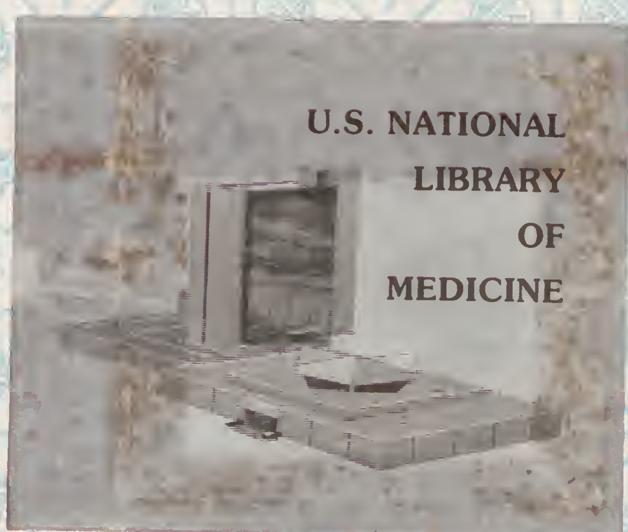
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FINAL REPORT

OF THE COMMITTEE

Chemical Section
National Safety Council

on

SPRAY COATING

National Safety Council
CHICAGO

FINAL REPORT

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Chemical Section
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SPRAY COATING

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Final Report

Of the Committee, Chemical Section NATIONAL SAFETY COUNCIL

on

Spray Coating

Introduction

The spraying of surface coatings by compressed air was first introduced in this country as a practical method about 1890. Although it was then a crude process it established a record for speed and economy and rapid improvement of mechanical equipment followed. Its real progress and more widespread use dates, however, from our entry into the World War in 1917, as it was then necessary to meet the production exigencies of that time. Since then engineering improvements in both spray-guns and exhaust ventilating equipment have been made frequently and will doubtless continue. Indeed, the manufacturers of both are to be congratulated on what they have done for the industry. Engineering improvements in the equipment have kept pace with the later scientific developments in the materials used. In this field also continued development may be expected. It should be remembered that it was the development of the spray painting machine which accelerated and made practicable the application of the modern quick-drying pyroxylin lacquer.

Spray coating is today being used extensively in the field of industry for finishing and refinishing, by contracting painters of buildings and structures; by large institutions, factories, railroads and shipyards; by federal, state, county and city government departments; by the automobile painting industry, in the finishing of furniture and in leather finishing. It has practically revolutionized the process of finishing and refinishing in industry, enabling mass production at lowered cost and greatly reduced operating space. It is reliably estimated that a large percentage of those products of American industries which require a surface coating (not finished by dipping or flowing) are now sprayed because of some particular advantage in the spraying method. Its wide use in industry has demonstrated its adaptability to the painting of interiors and exteriors of buildings and other structures where it has become a recognized tool of progressive master painters.

No widespread development of this sort takes place without passing through a period of adjustment. As usage expands, defects and dangers not previously recognized become apparent, among them the hazards affecting personal safety and health. Because of lack of exact knowledge involving certain phases, or misunderstanding of the process on the part of those not familiar with its operation, it is natural that there should arise at times controversial situations involving both understatement and exaggeration as to the degree of accident or health hazards incidental to use. Controversies of such a sort are apt to be destructive rather than constructive, with the result that real progress in the art is hampered and sometimes interrupted. There is a tendency always to seek remedy through prohibitive legislation rather than through intelligent investigation and voluntary correction. This is particularly true where physical health is involved, since under such conditions it is not difficult for the opponents to gain a sympathetic hearing.

What has been said in the preceding paragraph applies in most respects to the development of spray coating. Its use unquestionably involves accident and health hazards as is the case wherever an operator is brought into contact with harmful ingredients or impure atmospheres. This occurs even in brush painting, paint manufacturing and so forth. Some of these hazards are now obvious, while others, undoubtedly, are still obscure. In the past there has been no little controversy on the extent of these hazards, especially that of benzol poisoning. The paint and varnish industry itself recognized this and with commendable energy embarked upon an educational campaign to discourage the use of benzol by manufacturers and consumers. This effort followed closely on the general release of authoritative information on benzol poisoning as a result of the investigations carried on by the National Safety Council's Committee on Benzol.

Realizing that in such a controversial situation there was considerable danger to progress—the danger of destructive rather than constructive action—and appreciating the desirability of securing authoritative information upon which to formulate a guide to minimize any hazards to life or health which might be present, the National Safety Council, through its

Chemical Section, proposed that an investigation of spray coating be made under the auspices of a committee composed of representatives of groups interested in the subject and others who were qualified to give expert opinion. The intent of the investigation was to be unbiased fact-finding. There was no intention of formulating remedial measures solely for their use as basis for either legislation or state regulations; the information was to be placed at the disposal of every one as a contribution to existing knowledge and as an incentive (if it so proved) to accident prevention efforts. The importance and value of spray coating was recognized and it was earnestly hoped that, if serious hazards were revealed, means of obviating them without unnecessarily interfering with the industry would suggest themselves. No attempt was made to develop information as to the relative hazards of hand brush painting, nor to induce comparison between the merits or defects of the spray process with the hand brush process. In fact, at the moment, resources at the disposal of the National Safety Council for this investigation would not have permitted a study of the brush painting field.

Accordingly, the National Safety Council Executive Committee appointed a Steering Committee consisting of Messrs. A. L. Watson, Chairman, L. A. DeBlois, G. E. Sanford, S. E. Whiting, and A. W. Whitney. This committee, in turn, appointed the investigating committee (called the Spray Coating Committee) made up of representatives designated by interested Federal and State bureaus, universities, insurance bureaus, labor organizations, associations of manufacturers of materials and equipment used in spray coating, and users of the spray coating process. The entire personnel of the committee, with the affiliations of its members, will be found on Page 3.

The final report of this committee, which forms the body of this document, was adopted by the Spray Coating Committee at its final meeting on June 6, 1927, and, on recommendation of the Steering Committee, was approved by the Executive Committee of the National Safety Council, September 25, 1927. Two members of the Spray Coating Committee, Messrs. William J. Pitt and Wayne B. Thompson, prior to the final meeting of the Spray Coating Committee, had submitted detailed objections to the tentative conclusions reached by a majority of the committee as result of the field investigations. Each of these objections was given careful consideration at the June 6 meeting and voted upon, but the committee did not sustain these objections except in part. Thereupon the minority members voted against the adoption of the whole report and subsequently filed a minority report, consisting of a summary of their opinions with supporting data, including extensive citations from the committee's report and from the field data. As it is the opinion of the Steering Committee that the Spray Coating Committee gave full consideration to the points raised by the minority before the report was finally adopted, only the summary of the minority report is printed herewith. It will be found on Page 53. The remainder of the minority report can be obtained by those interested on application to the National Safety Council, 108 East Ohio Street, Chicago, Ill.

As regards the intrinsic merit of the work of the disinterested investigators and of the committee itself, we feel that a substantial and important contribution has been made toward more complete knowledge of the conditions surrounding the application of spray coating to manufacturing processes. It is earnestly hoped that the conclusions reached as result of these investigations will be applied constructively in accident prevention and health conservation.

A. L. WATSON, Chairman,
Spray Coating Steering Committee.
National Safety Council.

I. Historical Development of the Problem

It is only within the past ten years that possible health hazards in the use of the spray gun have been brought to the attention of industrialists. In Dr. Alice Hamilton's monograph on "The Hygiene of the Painters' Trade," published in 1913[1], there is no mention of spray coating. The first mention of this subject in the literature is found in a paper by Dr. R. P. Albaugh of Ohio in 1915[2]. Wade Wright in 1917[3] in a statistical table showing the cases of lead poisoning diagnosed during the first year of his industrial clinic at Boston includes a spray painter.

Five years later N. C. Sharpe published the first really extensive study of the process of spray coating from the standpoint of the hazard of lead poisoning at that time[4]. In this study a paint was made up in which the pigment consisted entirely of white lead, this being 60 per cent of the whole mixture. The liquid portion consisted mainly of linseed oil and turpentine in approximately equal parts. This mixture was diluted with benzine to the proper consistency for spray painting. Air pressure was kept between 35 and 55 pounds per square inch, and the spray was directed against a vertical wall. The experiments were done in a large room with a low ceiling, so there was a tendency for the fumes to roll back toward the operator. No direct draft for fume removal was in operation. Some specimens of air were collected by being drawn through suction cylinders containing water or dilute acid, the air being broken up by the finely perforated bulb on the suction tube. In the case of other specimens Duckering's method was used. Samples of air were taken at various positions likely to be occupied by the nose and mouth of the spray painter, 300 liters of air being used for each estimation. In order to study the distribution of the spray, porcelain plates varying in surface area from 12 to 50 sq. cm. were exposed horizontally in different locations for half hour periods. In estimating the samples for lead they were treated as if the lead was in organic combination.

During the three day experiment in spraying the wall, the operator worked from four to five hours daily. The urine for the 24 hours following showed the presence of 0.3 mg. of lead. The plates exposed for half hour periods indicated that with lead paints sprayed with the apparatus used at that time lead was deposited 11 ft. to the right of the operator and 3 ft. behind the operator.

In certain other studies the collecting apparatus was taken to a factory where small objects (1 to 2 sq. ft.) were spray painted in a cabinet provided with excellent suction. No lead was recovered from the air samples, although plates exposed at various points indicated that at certain positions in the neighborhood of the sprayer lead was deposited.

Various types of masks were tested in order to determine the degree of protection afforded the spray painter. In each case a duplicate air sample without protection was taken as a control. It was found in this study that fine wire gauze masks afforded no protection whatever. A mask of gauze and cotton made as thick as possible without causing uncomfortable or constrained breathing reduced the lead present in 10 cu. meters of air from 90 to 10 mgs. A mask of gauze, cotton, wool and charcoal reduced the lead from 104.2 mgs. to 3.33 mgs. This mask was so uncomfortable, however, that no workman would endure it and if worn comfortably it was found to be useless on account of entrance of air from the side. Masks of comfortable breathing thickness of gauze and cotton wool, moistened with a 5 per cent solution of sodium sulphide, reduced the amount of lead present from 232 mgs. to 12.4 mgs. per 10 cu. meters of air. A similar mask but dry, that is without sodium sulphide solution, permitted 11.7 mgs. per 10 cu. meters to pass through, whereas a moistened mask in the same test permitted but 5.8 mgs. to pass.

The author calls attention to the risk of poisoning from the inhalation of fumes of volatile substances used in paint, but concludes that there is no danger from lead poisoning in spraying small objects properly placed in an exhaust cabinet provided with efficient suction. On the other hand, he concludes that his experiments show that when lead is a constituent of a paint used in spraying walls inside a building there is real danger of lead absorption. In exterior painting he feels that there would probably be less risk from poisoning since the painter could take advantage of the prevailing air currents.

In 1924, Dr. Hamilton pointed out that the danger of the painter from lead poisoning had recently been increased by the very general adoption of the spray gun for painting all sorts of factory goods, large as well as small objects being painted in this manner, and recently the interiors of buildings[5]. She states that "experiments by the U. S. Bureau of Mines show that it is possible to construct a gas mask which will filter out oily droplets without becoming clogged, but it remains to be seen whether men will consent to work eight hours a day in a gas mask."

After the appointment of an advisory committee and the holding of public hearings, regulations governing

[1] Bulletin 120, U. S. Bureau of Labor Statistics, May, 1913.

[2] Albaugh, R. P. A Fatal Case of Slow Poisoning in the Person of a Young Man Employed as a Sprayer in a Varnishing Department, Ohio Public Health Journal, Vol. VI, No. 5, Nov., 1915, p. 512, also The Dangers Connected with the Spray Method of Finishing and Decorating, American Journal of Public Health, Vol. VII, No. 3, March, 1917, p. 279.

[3] Wright, Wade. An Industrial Clinic, Monthly Labor Review, U. S. Bureau of Labor Statistics, December, 1917.

[4] Sharpe, N. C. Report on an Investigation to Determine the Hazard to the Health of Operators Using the Spraying Machine for Painting: The Risk of Lead Poisoning. Journal of Industrial Hygiene, April, 1922, Vol. 3, p. 378.

[5] Hamilton, Alice. The prevalence and distribution of industrial lead poisoning. Journal of the American Medical Association, Aug. 23, 1924, Vol. 83, No. 8, p. 583.

spray coating were adopted in 1924 (revised in 1925) by the Industrial Commission of Wisconsin. In the spraying of buildings, ships and structures, these regulations fixed a maximum distance between the spray gun and the object to be treated, provided that respirators or other devices approved by the Industrial Commission must be worn and that exposed parts of the body should be covered by a non-drying oil, grease or cream. In the spray coating of other objects booths must be provided with exhaust ventilation, although the extent of such ventilation is only indicated in a foot-note as follows:

"In some instances an average flow of 200 cubic feet per minute per square foot of booth face area was found none too much for effective protection, and in other cases as low as 80 cubic feet per minute was found equally effective."

The next important step was taken in Pennsylvania[6] where an exhaustive study of the whole problem was initiated in the spring of 1925 under the State Department of Labor and Industry. This investigation—the first really comprehensive one which had been conducted anywhere—was directed by Professor H. F. Smyth of the Laboratory of Hygiene of the University of Pennsylvania in conjunction with Dr. Elizabeth E. Bricker of the Department of Labor and Industry. Thirty-two different industrial groups comprising 233 plants using the spray gun in production were visited and studied, many of them applying the spray to furniture or to small metal objects. Ninety-one analyses were made for benzol; 22 for lead; 26 for dust; 168 air velocity determinations were made. In all, 383 physical examinations were made and 43 specimens of urine were analyzed for lead. In addition to these field investigations Dr. Smyth and his associates conducted special studies on benzol concentration and exhaust ventilation in an experimental booth specially set up for the purpose in the Laboratory of Hygiene of the University of Pennsylvania.

The Pennsylvania study made it clear that there are three major health hazards which may be involved in the use of the spray gun for interior work under various specific circumstances. Where paints and enamels contain an important proportion of lead, plumbism may result; where benzol thinners are used in connection with paints or lacquers sprayed upon the interior surfaces of structures or upon manufactured articles, there is danger of benzol poisoning; vitreous enamel used in making bath tubs and similar vitreous ware frequently contribute to the atmosphere sufficient finely divided silica to create a silicosis hazard. No clearly marked clinical cases of poisoning were revealed in the course of the Pennsylvania studies but an appreciable proportion of workers exposed to benzol showed the disturbed blood picture characteristic of early benzol poisoning and it appeared that the benzol content of lacquers and similar finishes is highly variable and uncertain and that, even when not originally present, benzol is frequently added in the form of cheap lacquer thinners. Exposure to benzol was therefore at that time much more common than was generally realized. Dr. Smyth and his associates found that both benzol and lead were often present in large amounts in the air breathed by the industrial sprayer and that of the 127 lacquer sprayers examined 5+ per cent showed white blood cell counts indicative of benzol poisoning and 39+ per cent gave a disturbed blood picture. The Pennsylvania study also revealed that 18 per cent of the men engaged in paint spraying showed stippled cells or polychromatophilia (the property of being stainable with certain stains). In the Pennsylvania investigation of eight spray painters engaged in building or structural painting, none were found to have lead poisoning.

II. Initiation of the Present Investigation

Recognizing the importance of an authoritative examination and study of the health hazards of spray coating by an unbiased body, and as yet unaware of the Pennsylvania study, the National Safety Council at its Cleveland Safety Congress in 1925 created a special steering committee to organize an intensive study of the problem and appointed Mr. A. L. Watson as chairman. The Steering Committee in turn appointed for this purpose a Spray Coating Committee of 23 members representing Federal and State bureaus, universities, national health organizations, insurance companies, organized labor, and manufacturers of materials and equipment used in spray coating, with Professor C.-E. A. Winslow of Yale University as chairman. The Committee met in New York for organization on March 5, 1926, and elected Dr. Leonard Greenburg of the United Public Health Service secretary. A tentative program of study was drawn up and a request made for an appropriation of $10,000 to finance it.

The National Safety Council appropriated the necessary funds and at a second meeting of the Committee held on June 4, 1926, it was decided to invite Dr. H. F. Smyth and his associates, who had recently completed their study in Pennsylvania, to undertake the actual conduct of the new investigation. At the same time the United States Bureau of Mines was asked to conduct certain special studies of the efficiency of respirators which it was felt were necessary to supplement existing knowledge of this subject.

The Committee was exceedingly fortunate in thus securing the services of Dr. Smyth and his colleagues, who were even then in the midst of similar studies and were thus able to begin active work without the delay incident to coping with a new problem. Associated with Dr. Smyth were H. F. Smyth, Jr., and Dr. E. F. Pike, who conducted field and chemical studies. Blood counts were made by Dr. Miriam Izard, J. R. VanMeter and Miss A. T. Marston. Some blood counts, as well as urine analyses, were made by Dr. Haluska of Detroit.

[6] Smyth, Henry Field. Hazards of Spray Coating Processes Investigated. The Nation's Health, May, 1927, Vol. 9, No. 5, p. 24.
Smyth, Henry Field. Spray Coating Processes. American Journal of Public Health, May, 1927, Vol. 17, No. 5, p. 440.

III. Scope of the Investigation

The use of the spray gun had penetrated so many industries and was employed for such a wide variety of purposes that it was obvious to the Committee that the investigation must be confined to the study of the more significant hazards. Even therein, with the time and money at its disposal, it could not hope to accomplish a searching investigation which would accurately measure the degree of hazard or establish any considerable volume of reliable information. The course that seemed best was to select a locality which promised a reasonable field in which conditions could be studied intensively rather than broadly. It was recognized that this might not yield results that were typical of the industries studied, or typical of the spray painting occupation as a whole. It would constitute, however, a forward move which, with the results of the Pennsylvania study, could be expected to cast additional light on an obscure problem for which industry was demanding a constructive solution.

The three outstanding health hazards arose obviously from the use of benzol, lead and silica, the latter not the siliceous pigments ground in linseed oil used sometimes as a constituent of paints but the free silica that might be present in vitreous enamels. The primary objective, therefore, was the detection of benzol poisoning, plumbism and silicosis and *their prevention.* Such cases were to be sought principally among sprayers of lacquer, leaded undercoats and vitreous enamels. The first two of these pointed directly to the field of automobile finishing, as this might be expected to yield satisfactory information on both benzol and lead; vitreous enamel spraying should yield information on both lead and silica. The selection of these industries, therefore, was economical and also desirable in view of the fact that in Pennsylvania it had been impossible to study large-scale automobile body finishing or individuals who had been subjected to long exposure in vitreous enameling processes.

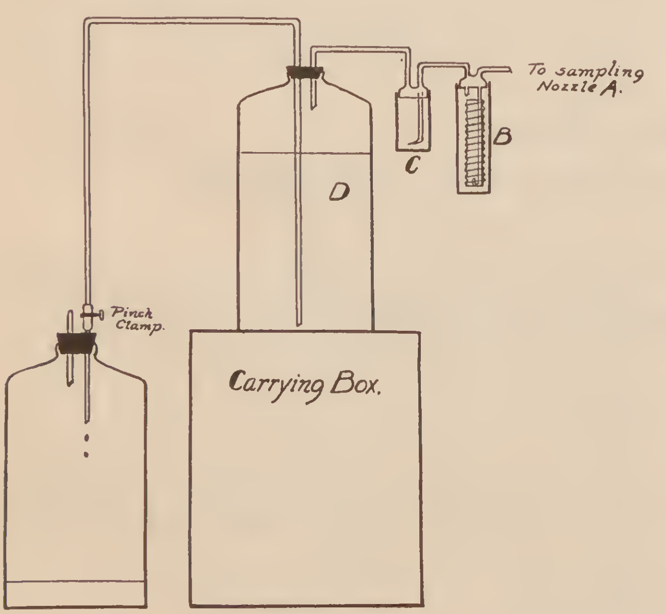

Figure 1. Sampling apparatus.

In making this selection (or reaching its final conclusions) the Committee could not be guided in any way by statistical information on occupational disease occurrence among spray operators, because nothing reliable of the kind existed. It is generally conceded that many cases of chronic benzol poisoning, plumbism and silicosis are undetected, pass for other diseases or, at least, are not reported as occupational diseases. Furthermore, no information is available on the corresponding exposure to the hazards in question so that their relative severity cannot be ascertained in industry as a whole or in any branch of industry or in any specific occupation. We cannot say, for example, on the basis of statistical knowledge whether brush painters are more prone to plumbism than undercoat sprayers, or whether there is a relatively higher death-rate from silicosis in granite cutters than in enamel sprayers. In this matter the Committee at once recognized the futility of attempting any statistical exploration; general judgment could be the only guide.

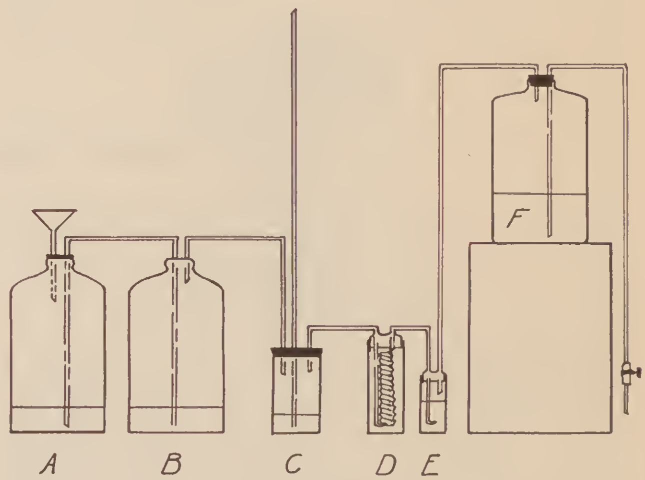

Figure 2. Calibration scheme.

The activities of Dr. Smyth's staff began in fact on June 7, and, after assembling equipment and conducting certain preliminary studies, they proceeded to Detroit and Toledo where it had been decided that the most favorable field could be found. Through the courtesy of Dr. Henry F. Vaughan, Commissioner of Health of Detroit, laboratory facilities of the most excellent character were generously placed at their disposal. During the period spent by the Field Staff in Detroit tests were made in four automobile body plants, in two automobile factories and in three vitreous enameling plants. Employees of three contracting painters were also studied. In Toledo study was made of a large automobile plant, a vitreous enamel plant and a plant making spray painting equipment. The employees of six contracting painters were also

examined. Enameling plants in Mansfield and in Cleveland were also visited and studied.

Throughout the study the effort was made to observe conditions existing in the industries which were being examined, to determine the degree of atmospheric pollution in the air breathed by the operator and to correlate as far as possible these engineering and chemical findings with the actual condition of the operatives as revealed by careful clinical examination and by refined blood tests and examinations of body discharges. Altogether 29 different plants (or groups of workers) were studied. Eighty-six air tests were made for benzol, 27 for lead and 33 for silica. A total of 354 physical examinations were made, including 349 blood tests.

The field work was completed by September, 1926. On October 18 the Committee held its third meeting to hear Dr. Smyth's preliminary report (which was also presented informally at the Detroit Safety Congress in October). During the winter the results were analyzed in detail and a report drafted. This report with the comments made by members of the Spray Coating Committee was submitted to an Editing Committee. Their final draft was considered by the Spray Coating Committee and, with modifications, was finally approved and adopted at a meeting held on June 6, 1927.

IV. Spray Paint Constituents

A paint is a mixture of pigment and vehicle (liquid portion) with which additional thinning liquid may sometimes be used. The following is a summary of the substances usually encountered in various types of paints:

Interior Paints. For interior walls and ceilings of dwelling houses, hotels, factories, etc., lead-free prepared paints are quite widely used in spray painting work. They contain as a rule the following solid ingredients: Lithopone, zinc oxide, titanium oxide pigments, calcium carbonate, barium sulphate, china clay, and other siliceous earth pigments.

The liquid materials used in spray paints for interior surfaces, which are applied possibly to the greatest extent, are vegetable drying oils, chiefly linseed oil and chinawood oils.

The thinners almost universally used with these interior spray paints are mineral spirits (a high boiling point distillate from petroleum) and, to a very minor extent, turpentine. The main use for turpentine in paints is where the paint is mixed by hand rather than in prepared form.

Exterior Paints. For general exterior painting work upon dwellings and other structures where white and light tints are desired, the pigments most commonly used are basic carbonate white lead, basic sulphate white lead, zinc oxide, leaded zinc oxide, titanium oxide pigments, lithopone, china clay, and other siliceous earth pigments. The tinting colors used in these white paints, where a tinted paint is desired, are usually in very minor proportions and consist of such tinting colors as Prussian blue, chrome green, carbon black, chrome yellow, iron oxides, ochre, sienna, etc.

Paints for exterior work contain usually not over 10 per cent by weight of volatile materials, the balance being solid pigments and liquid drying oils. Many of these paints contain not over 6 to 7 per cent by weight of volatile materials, and of this percentage in

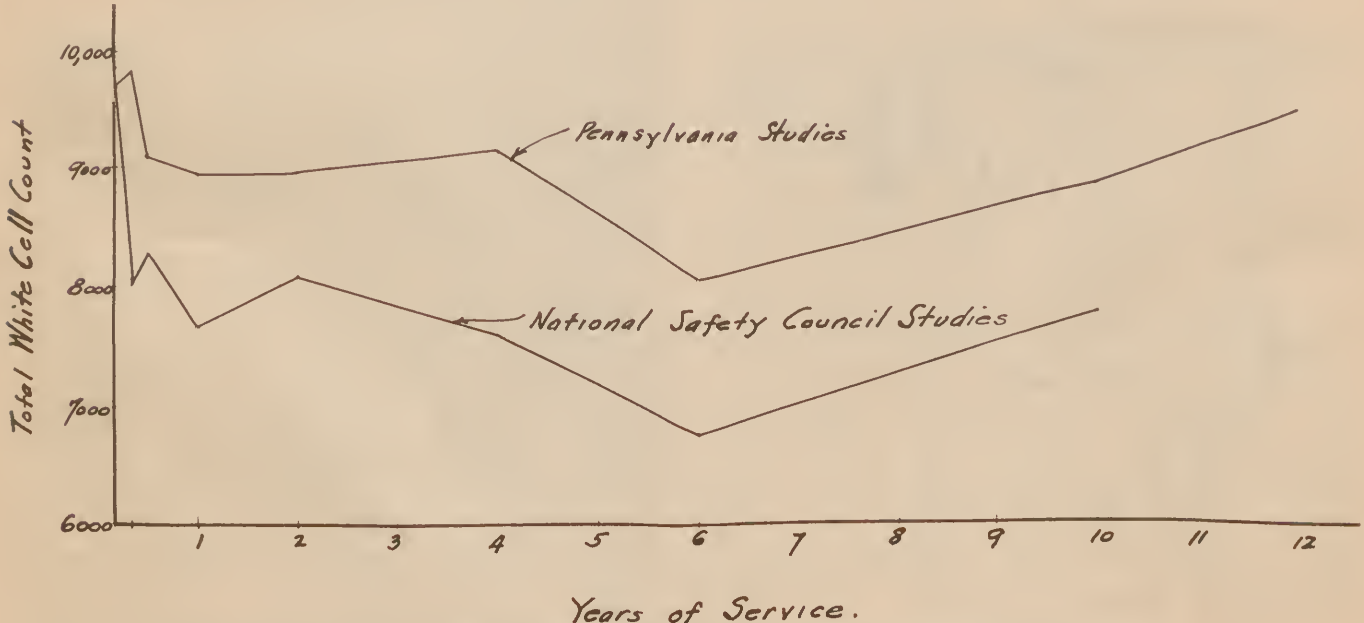

Figure 3. Lacquer sprayers; showing relation between total white cell count and duration of occupation.

many cases the volatile is entirely mineral spirits, although in some cases from 2 to 7 per cent may be turpentine.

In finishing railway cars, such as freight cars, coal carriers, etc., and structural steel the paints employed are almost invariably made with carbon black or mineral earth pigments such as mineral brown, ground in raw linseed oil or in heat-bodied oils and varnishes. As a rule, the volatile portion of such paints will run from 10 to 20 per cent by weight. In this volatile portion in most instances there is no turpentine, the volatile portion almost invariably consisting of straight mineral spirits. No benzol or other aromatic hydrocarbons are employed in such paints.

Lead. Lead is also used as a primer on structural steel.

Lacquers. Nitrocellulose lacquers are made with soluble nitrated cotton, gums such as dammar, ester gum, etc., solvents and plasticizers. The solvents almost universally employed are amyl acetate, butyl acetate, ethyl acetate, butyl propionate, acetone, ethyl alcohol, and butyl alcohol. While benzol was at one time quite widely used in lacquers, its use has now been discontinued by practically every manufacturer of lacquer because of its recognized health hazards. It has been replaced with toluol. Wherever ethyl alcohol is used, it is denatured and may contain up to 5 per cent of wood alcohol or 0.5 per cent benzol in accordance with the requirements of the U. S. Government denaturing formulae. Finished lacquers in which denatured ethyl alcohol is used, however, probably never contain as much as one per cent of wood alcohol. Some other types of solvents are being experimented with in a limited way and in small amounts. These include turpentine solvents, cyclohexanol, and diacetone alcohol. The total amount of volatile material in lacquers probably ranges from 40 to 70 per cent by weight. Nitrocellulose enamels contain in addition to the above ingredients a great variety of pigments. For certain colors it is necessary to use lead compounds, particularly lead chromate, which may be present in an amount up to 10 per cent by weight.

As additional thinning mediums, toluol and xylol are used almost exclusively in high grade lacquers. According to the findings of the Benzol Committee they are relatively harmless.

The so-called plasticizing mediums used in lacquers are very high boiling point materials that do not

Figure 4. Respirator with rubber tube to supply fresh air.

evaporate rapidly and which largely remain in the film. These are such substances as tri-cresyl phosphate, dibutyl phthalate, diamyl phthalate, diethyl phthalate, etc.

V. Benzol Poisoning as a Spray Coating Hazard

No attempt will be made to review the extensive literature of benzol poisoning since the reader who desires to go more deeply into the subject will find it very fully presented in the report of the Committee on Benzol of the National Safety Council issued a year ago.[7] In general it is only necessary to recall that benzol is a highly toxic substance causing a complex of symptoms which may be summarized as follows: (a) General systemic disturbance as evidenced by headache, dizziness, weakness, loss of appetite and loss of weight; (b) Pallor, shown by blood examination to be due to true anemia; (c) Marked reduction in white blood cells (revealed, of course, only by microscopical examination); (d) Bleeding from nose, gums, vagina and bowels with the development of purplish spots caused by small hemorrhages within the tissues; (e) Sore and spongy gums and burning of eyes and throat; (f) Shortness of breath and tightness of chest; (g) Sometimes, abdominal pains, nausea and vomiting; (h) Sometimes, slight tremors, visual disturbances and abnormal sensations, rarely convulsions and delirium; (i) Rarely, rashes and skin eruptions.

Benzol poisoning may be detected in its very early stages by a decrease in the number of white cells present in the blood and according to the findings of the Committee on Benzol a white cell count below 5625 per cubic millimeter of blood may be considered a reasonably clear index of latent benzol poisoning.

[7] Final Report of the Committee on Benzol, Chemical and Rubber Sections, National Safety Council, May, 1926.

Injuries of this sort to the blood forming organs were found in the studies of the Committee on Benzol to be associated with even very low concentrations of benzol in the atmosphere (100 p.p.m.) while Legge states that 550 p.p.m. is likely to be associated with definite clinical poisoning.[8]

The Committee on Benzol concluded that masks and respirators depending on the filtration principle should not be relied upon to protect the worker against ordinary routine exposure to benzol fumes, since such devices cannot be made efficient without making them too uncomfortable to be worn continuously. It urged that, wherever benzol was used as a solvent or vehicle under conditions which almost of necessity permit more or less evaporation into the atmosphere, effective exhaust ventilation should be provided together with monthly medical examinations including blood tests to detect incipient poisoning. It finally concluded that the serious attention of manufacturers now using benzol should be directed to the substitution of some less harmful solvent for so dangerous a substance.

VI. Results of Benzol Poisoning Investigation

The detailed findings of Dr. Smyth in the studies conducted for this Committee, so far as they bear on the benzol hazard, will be found in Section I of Appendix I. They deal with 160 workers employed in spraying lacquers in seven different automobile or automobile body plants.

In two of the seven plants studied the lacquer was thought to contain little or no benzol, in one the men had been on strike and had thus been free from recent exposure, in one plant the composition of the material was variable and in three benzol was definitely present (1.5, 5 and 9 per cent respectively). The booths or tunnels in which the spraying was performed were all provided with systems of local exhaust ventilation but the average air velocities in all but one plant (in which the average velocity was 147 feet per minute) were generally low, ranging from 45 to 73 linear feet per minute.

Determinations of benzol in the air were made in only 5 of the plants studied with average results varying from 375 to 1880 parts of benzol per million. Individual test results, however, varied widely and were not closely correlated with the benzol content of the lacquer, though they did indicate that the benzol hazard in this industry is a very real one.

The following comparison of the low exposure plants (the two using lacquers supposed to be nearly free from benzol and the one from which the workers had recently been absent on account of a strike) with the other four plants which, for the sake of comparison, were termed "high exposure plants" brings out some very suggestive differences. First, the men in the high exposure plants reported more than twice as many subjective complaints as the men in the low exposure plants (particularly constipation, dizziness and dyspnea), and the proportion of these complaints reported showed generally an increase with length of service. Second, the men in the high exposure plants showed a larger proportion of low red cell counts: 17 per cent with less than 4 million red cells, as compared with 7 per cent for the low exposure plants; while the white cell count, the most significant index of incipient benzol poisoning, gave an even more striking contrast. Taking the Benzol Committee limit of 5625 white cells per cubic millimeter as a dividing line, only 1 man out of 69 in the low exposure plants fell below standard while in the high exposure plants 19 out of 91 men examined gave a disturbed blood picture. Here, as in the case of subjective symptoms, Dr. Smyth's data show a striking increase in disturbed blood pictures with increased length of service. Finally, the analysis of the combined blood picture and subjective symptoms for individual workers shows that out of the 69 men in the low exposure plants only 1 gave a picture suggestive of a diagnosis of benzol poisoning while there were 7 such men out of 91 subjects employed in the high exposure plants.

From these results it seems very clear to the Committee that the spraying of benzol lacquers with the spray gun constitutes a real health hazard under the conditions found by Dr. Smyth.

VII. Lead Poisoning as a Spray Coating Hazard

The whole subject of industrial lead poisoning has been so admirably reviewed by Aub, Fairhall, Minot and Reznikoff[9] that it is unnecessary to discuss the general subject. It need only be recalled that the ingestion of lead may be detected by analyses of feces and the absorption of lead by analyses of urine. Lead poisoning in its incipient stage is indicated by a characteristic stippling of the red cells of the blood.

In the present investigation, Dr. Smyth studied 170 men, including 97 men working in six different automobile or automobile body plants spraying paints and undercoats, 38 housepainters using the spray gun on inside or outside work and 35 men applying vitreous enamel to castings. The materials used by the undercoat sprayers contained 10 to 19 per cent of lead. The paint used by the indoor painters contained less than one per cent and that used by the outdoor sprayers, 19 per cent. In the vitreous enamel plants the soluble lead varied from 0.4 to 20 per cent.

In the booths used for spraying paints and undercoats, the average exhaust velocity produced at the working face by the local ventilation provided was again low (averaging 28 to 75 linear feet per minute), except in one plant where an average velocity of 160 feet was recorded. Conditions in the vitreous enamel plants were somewhat better, with velocities averaging

[8] Legge, T. M. Chronic Benzol Poisoning. Jour. Indust. Hyg., March, 1920, I, No. II, p. 539.

[9] Lead Poisoning. Aub, J. C., Fairhall, L. T., Minot, A. S. and Reznikoff, Paul. Medicine Monographs, Vol. VII, 1926.

between 0 and 212 feet. The amount of lead determined in the air was low in the case of two undercoat plants and in the case of the indoor house painters, but was high in the three other undercoat plants (32 to 164 mg. lead per cubic meter of air).

Since our resources did not permit of both procedures, it was arranged to have chemical examinations made of feces rather than of urine. Urine studies would, of course, have been more significant of actual lead absorption but lead in the feces is at least indicative of the ingestion of the poison and it was desired to secure data comparable with those obtained by the U. S. Public Health Service in its study of tetraethyl lead. Of the group of 65 spray painters examined 17 per cent showed more than .03 mg. lead per gram of feces as against none in the normal persons and 34 per cent in those workers exposed to a highly intensive lead hazard, in the Public Health Service study.[10] Our group includes two structural painters one of whom showed over .03 mg. of lead per gram of feces.

Of the 170 workers subjected to medical examination 19 per cent complained of digestive disturbances, 10 per cent of loss of weight, 9 per cent of constipation, 8 per cent of loss of appetite and 3 per cent of gastric pain, while 5 per cent showed the characteristic blue line on the gums. Of the 39 structural painters examined 4 complained of digestive disturbances, 3 of loss of weight, 4 of constipation, 1 of loss of appetite, 2 of gastric pain, and only 1 showed a blue line on the gums. Owing to the small total of men in this class the figures are given as numbers of men, rather than per cent of the total.

Blood tests failed to show any extensive prevalence of anemia but counts of stippled cells made on a selected group (See Appendix I, p. 23, for basis of selection) yielded striking results, 7 out of 16 men giving a count of over 100 stippled cells per 100,000 total cells as against only 1 out of 15 lacquer sprayers examined as a control. This result, like the data for lead in feces, would tend to place interior spray coating with lead paints in the class of hazardous industrial occupations. Dr. Smyth's data, as given in Section II of Appendix I, indicates that, out of 97 undercoat sprayers, 6 individuals gave a complex of signs and symptoms suggestive of incipient lead poisoning. Among 38 housepainters there were 3 cases of this kind, while 37 sprayers of vitreous enamel containing lead gave 5 more.

Figure 5. Helmet with hose to supply fresh air.

Again, as in the case of benzol, we may conclude that the lead poisoning hazard in spray coating as at present conducted in the industrial plants examined is a distinctly significant one.

VIII. Silicosis as a Spray Coating Hazard

The spraying of vitreous enamels in the manufacture of sanitary ware, refrigerator linings, stove parts, milk tanks, etc., may involve two distinct hazards, that of lead poisoning when the substance sprayed contains lead and that of silicosis when finely suspended silica dust is present. The latter problem will be found fully discussed in its more general application in a monograph by Greenburg.[11]

The present study covered 35 workers (of whom 2 were women) in 6 groups employed in spraying vitreous enamel on castings and 26 workers (of whom 19 were women) in 4 groups spraying vitreous enamel on sheet metal. The enamels sprayed on castings included a substantial proportion of lead (4-26 per cent total lead, 0.4-20 per cent soluble lead) with a relatively low percentage of silica (21-37 per cent). On the other hand, the vitreous enamels sprayed on sheet metal contain little or no lead and a higher proportion of silica (43-47 per cent). The sprayers on castings have already been included in our earlier discussion in the groups exposed to the lead hazard; both groups of vitreous enamel sprayers (61 in all) furnish material for an estimate of the silicosis hazard.

According to the experience of English students of

[10] The Use of Tetraethyl Lead Gasoline in Its Relation to Public Health. Public Health Bulletin No. 163, Treasury Dept., Washington, D. C., 1926.

[11] Greenburg, Leonard. Studies on the Industrial Dust Problem. Public Health Reports, Feb. 13, 1925, pp. 291-309; April 17, 1925, pp. 765-766, and July 31, 1925, pp. 1591-1603.

industrial hygiene marked success in protecting the health of the workers has been attained in pottery manufacture by the use of a low solubility lead glaze, a bi-silicate of lead yielding less than 5 per cent of soluble lead. This type of fritted lead silicate, if it is possible to use it in spray coating, should also avoid the danger of silicosis. We have no information as to whether such materials are in the market in this country but that the practice is not general is indicated by Dr. Smyth's analyses which show that in four out of five instances most of the lead present was in soluble form. The possibility of preparing a vitreous enamel so compounded as to contain no important proportion of either free lead or free silica should be given vary careful study.

Measurements of air velocity showed that in the booths where vitreous enamel was sprayed on castings the exhaust was reasonably effective with velocities averaging 123 to 212 feet per minute. In the booths where sheet metal was treated the apparatus was much less efficient, giving average velocities varying from values too low to be measurable up to 125 feet per minute.

Dr. Smyth's dust counts at the working face of these spray coating booths were highly significant. The one plant equipped with a really adequate system of ventilation giving an air velocity averaging 212 linear feet per minute yielded an average dust count of only 400,000 particles per cubic foot. Two other plants with exhaust velocities of between 123 and 130 feet, respectively, gave average dust counts of between 5,000,000 and 24,000,000 particles per cubic foot. The plant with an exhaust system so poor as to give no measurable velocity showed an average of 445,000,000 particles per cubic foot.

It seems clear to us from these observations that an exhaust velocity of 130 linear feet per minute may be insufficient to properly protect the vitreous enamel sprayer from dangerous exposure to silica dust; but that an exhaust velocity of over 200 linear feet proved adequate for the purpose in the instance studied.

The physical complaints reported by the sprayers of vitreous enamels were more numerous than in the case of the other groups studied and this was true not only for the sprayers on sheet metal, who were chiefly women, but also for the male sprayers on castings. It is particularly notable that dizziness was reported by 31 per cent of the sprayers on castings and 27 per cent of the sprayers on sheet metal; loss of weight by 23 per cent of the sprayers on castings and 19 per cent of the sprayers on sheet metal; dyspnea by 17 per cent of the sprayers on castings and 27 per cent of the sprayers on sheet metal.

The most direct measure of the silicosis hazard can, of course, be made by radiographic examination and readable pictures were obtained for 32 different individuals. Twenty-three of these 32 workers had been employed for less than three years at this type of work and all of the 23 plates from these workers were negative. Of the 9 workers employed for more than three years, on the other hand, two gave a picture interpreted by the expert who read the plates (Dr. H. K. Pancoast) as silicosis, and a third as probably silicosis.

IX. Protecting Spray Coaters by Local Exhaust Ventilation

Recognizing the very real hazards to which the spray coater may be exposed from benzol, from lead and from silica dust, it is next essential to consider how he can be protected from such danger.

The first type of protection to which we naturally turn is that of local exhaust ventilation; and in one instance, that of spraying vitreous enamel upon castings, we have fairly clear evidence of the value of such equipment. In the vitreous enamel plants with exhaust ventilation amounting to 130 linear feet per minute or less relatively high dust counts were found with suggestive evidence of plumbism. In one plant studied (Plant 19), however, we find a very different picture. Here 14 men were employed in spraying a compound containing 4% of lead and 37 per cent of silica. With an exhaust ventilation varying from 166 to 257 linear feet the dust counts were consistently under 600,000 particles per cubic foot and no case of silicosis was found in a series of X-rays covering all the fourteen individuals. It would seem probable from these findings that exhaust ventilation of 200 linear feet per minute may adequately protect the worker against the silica hazard in the spraying of vitreous enamel. Further studies may show that exhaust rates lower than 200 linear feet per minute may prove adequate with improved arrangements of booth and spray gun.

As regards lead, if we compare the exhaust ventilation in the various plants spraying lead with the lead content of the air respired by the worker we find a very high degree of atmospheric pollution (32-164 mg. lead per cu. m. of air) in three undercoat plants associated with poor exhaust ventilation (28-54 linear feet per minute). There was suggestive evidence of plumbism in a vitreous enamel plant with an exhaust of 130 feet and in another with an exhaust of 123 feet. On the other hand, in an undercoat plant with an exhaust of 160 feet and in a vitreous enamel plant with 212 feet no cases were found.

From this evidence, it may be concluded that an exhaust velocity of 130 linear feet is probably inadequate for the protection of the spray coater against lead poisoning, though the data are scarcely sufficient to state whether or not an exhaust of 150 feet would or would not in general provide satisfactory protection. Further study may make a more definite standard possible

For benzol we have even less information. Of seven plants studied six had average exhaust velocities under 75 feet per minute. In one of the six satisfactory

benzol determinations were not obtained; the other five had very high benzol concentrations in the air respired by the worker. The seventh plant had an average exhaust of 147 feet, but here again no satisfactory air analyses for benzol were obtained, yet in this plant, four out of eleven men showed low white counts and one a complex of symptoms suggesting benzol poisoning.

In the Pennsylvania studies in experimental booths fitted up at the University of Pennsylvania Dr. Smyth conducted an extensive series of tests on the relation between exhaust ventilation and benzol concentrations in the air when the gun was used to spray various lacquers containing from 0.7 to 9.2 per cent benzol. Full details will be found in the Pennsylvania report, but the main results may be cited as follows:

It would seem reasonable to conclude from this table that an exhaust velocity of 200 linear feet per minute will offer reasonably effective protection against benzol in the case of booth spraying. It will be noted that this is also the velocity found effective in actual practice in the case of vitreous enamels. We can see no justification for specifying any lower exhaust velocity where benzol is liable to be present, since according to these data exhausts between 150 and 199 linear feet give 14 per cent of all observations over 100 p.p.m. of benzol and 5 per cent over 100 p. p. m.—a distinctly hazardous concentration.

TABLE I

Results of Pennsylvania Experiments on Relation between Exhaust Ventilation and Benzol Concentration in the Air

Exhaust Velocity ft. per min.	Cumulative percentages of results falling in each concentration group at given exhaust velocities. 0 p.p.m.	Under 50 p.p.m.	Under 100 p.p.m.	Under 150 p.p.m.	Under 200 p.p.m.
0– 49	25	38	63	75	75
50– 99	49	77	90	92	97
100–149	58	77	88	95	98
150–199	57	76	86	95	95
200 plus	75	88	85	100	100

X. Protecting the Worker by Masks or Respirators

The second possibility of protecting the worker against the hazards of spray coating with such materials as lead, benzol and silica lies in the wearing of a mask or respirator and this is, of course, the only type of protection which can be employed with certainty in the case of indoor spraying without a booth or equivalent ventilation.

Masks and respirators are of two distinct types, those which depend on the principle of filtration (with or without chemical absorption) and those which depend on the provision of a supply of pure air by positive pressure.

The problem of the efficiency of the first class of respirators seemed to require detailed experimental

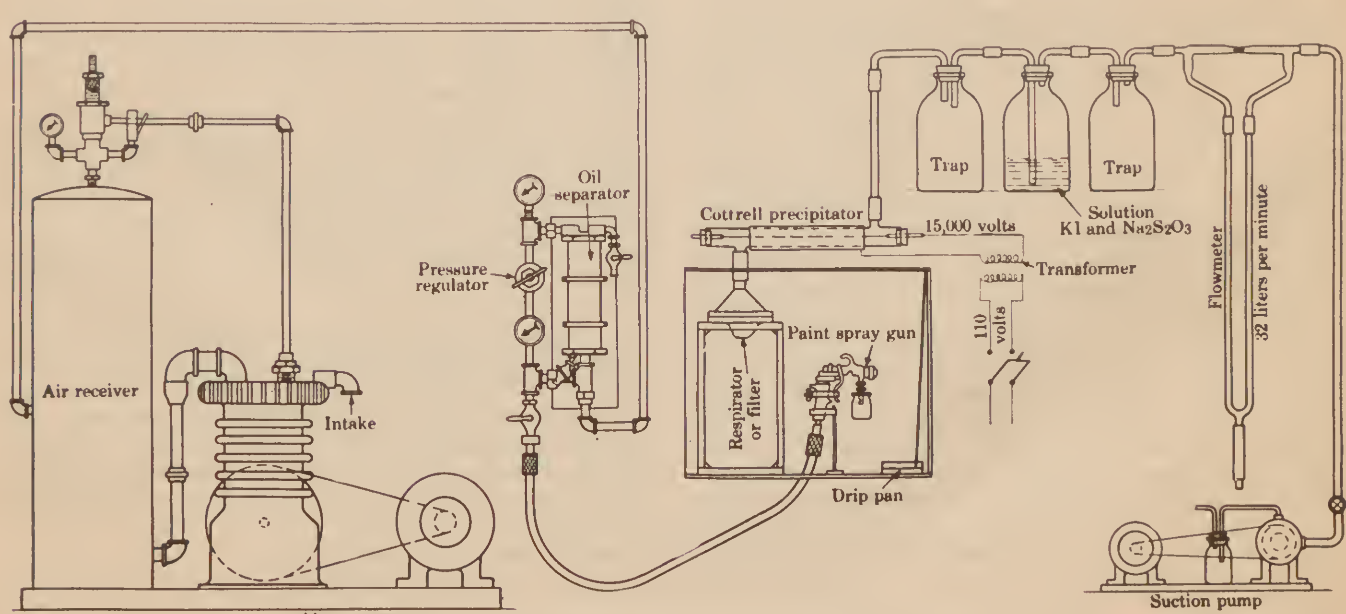

Figure 6. Apparatus for testing respirators filtering paint mist.

study and we were fortunate in securing for the purpose the cooperation of the U. S. Bureau of Mines. Through the courtesy of Mr. Scott Turner, Director of the Bureau, Messrs. S. H. Katz and F. H. Gibson were assigned to this work, the cost of the study being defrayed by the National Safety Council.

so that our data do not yield much hope of securing complete protection by any filtering device which is not too impervious to be worn with reasonable comfort.

To bring out the relation between filtering efficiency and resistance we have prepared the table below from all the Katz and Gibson data on lead removal. It is evident that as one approaches an effective purification one also approaches an interference with respiration which makes it impossible for the device actually to be employed in any approximately continuous process. Furthermore, it should be remembered that these tests were made with absolutely tight fittings and that in practice the efficiency might be very much lowered by *leakage* about the junction with the face.

TABLE II

Relation between Filtering Efficiency and Resistance to Respiration.

Resistance inches of water	Per Cent Removal of Lead: Under 60	61–80	81–90	91–93	94–96	97.0 97.9	98.0 98.9	99.0 99.3	99.4 99.6	99.7 and over
0–0.5	5	2	3	2	4	2	1			
0.6–0.9		1	1	1	2		1	1		
1.0–1.9					1	2		1	3	
2.0–2.9							3	1		
3.0–3.9							1	1	2	2
4.0–10.0										1
11.0 and over							1		1	1

The detailed results of this investigation are presented in Appendix II and need only be summarized here. A paint containing 100 grams of white lead paste in 50 c.c. of linseed oil and 25 c.c. of benzol was discharged by a spray gun under a pressure of 20-30 pounds into a chamber, from which air was drawn off at a rate of 1.13 cubic feet per minute, approximately the rate of respiration of a man performing vigorous physical work. In tests for lead the air thus drawn off was passed through the mask or respirator (or the special filtering material studied) and thence to a Cottrell precipitation tube where the lead passing the filter was precipitated by a high tension electric current. Comparison of the lead retained by the filtering material with the sum of the filtered and precipitated lead gave the per cent purification effected.

In planning this work it was assumed that for complete protection against lead a filter respirator should be capable of reducing an atmospheric concentration of 200 mg. lead per cubic meter to one of 0.6 mg.—a reduction of 99.7 per cent (See "Lead Poisoning," by Aub and others, reference,[9] p. 12). It will be noted from the data in Appendix II that only two of the actual respirators tested (Table I) and one of the special filtering materials tested (Table II) met such a specification. These devices were a respirator with two filters (each of 10 plies of gauzy tissue paper) plus a charcoal cartridge, and an Army Gas Mask with 2 cotton wool filters plus 600 c.c. of charcoal. The special filtering material was made up of three layers of chemical filter paper (S. & S. No. 589, black label) which showed a high efficiency. With a respirator and Army Gas Mask the resistance to air flow at the end of half an hour was between 3.8 and 4.4 inches of water, but in the case of the chemical filter paper it was 44.0 inches. It is impossible for a man to do vigorous physical work while wearing a respirator with a resistance of over 2 inches of water,

In studying the efficiency of respirators with regard to benzol a similar procedure was employed, except that the amount of benzol remaining in the filtered air was determined by an interferometer calibrated against synthetic mixtures of benzol and air.[12] It was assumed that an efficient respirator for use against benzol must be capable of reducing a concentration of 2000 p.p.m. of benzol to one of 75 p.p.m.—a reduction of 96.25 per cent. The various types of purely mechanical filters, of course, have no effect in restraining benzol vapors; some chemical absorbent is essential for such purpose. Three of the devices studied, the Gardner respirator (with about 5 grams of charcoal granules interspersed in cotton), the Pulmosan respirator containing activated charcoal, and the Army Gas Mask, promised some degree of effectiveness, but only the latter proved really adequate. The Gardner respirator showed no noticeable decrease in benzol and the Pulmosan cartridge reduced a concentration of 420-1360 p.p.m. of benzol to 75 p.p.m., for only 19 minutes. The Army Gas Mask gave an atmosphere of less than 75 p.p.m. for 250 minutes. The Army Gas Mask is, therefore, effective, but is, of course, altogether too cumbersome and uncomfortable to be worn for any continuous period during work of this sort.

In the case of silica dust it has been suggested that an efficient respirator should reduce a dust count of 200,000,000 dust particles per cubic foot to one of 200,000[13] dust particles per cubic foot, a reduction of

[12] Katz, S. H., and Bloomfield, J. J. Gas Masks for Gasoline and Petroleum Vapors. Technical Paper 348, Bureau of Mines, 1924.

[13] Winslow, C.-E. A., Greenburg, L., and Angermyer, H. C. Standards for Measuring the Efficiency of Exhaust Systems in Polishing Shops. Public Health Reports, 1919, Vol. 34, p. 427.

General Report of the Miners' Phthisis Prevention Committee. Union of South Africa, 1916. Final Report of the Miners' Phthisis Prevention Committee. Union of South Africa, 1919.

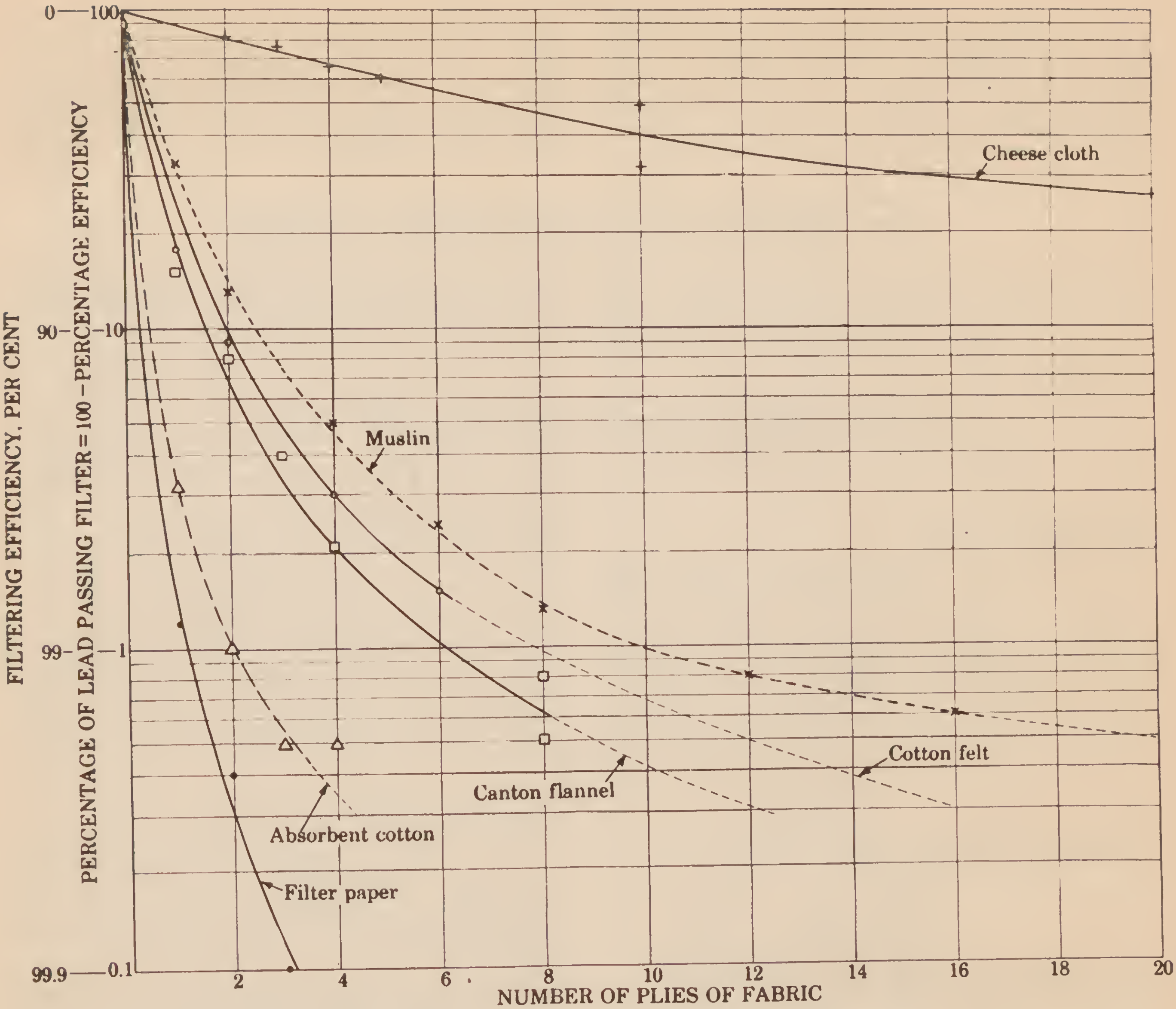

Figure 7. Efficiencies of various multiple fabric filters in filtering lead from paint spray.

99.9 per cent. None of the filters tested gave such a degree of efficiency, the nearest approach to it being obtained with 16 layers of bleached muslin and with 4 layers of chemical filter paper. In both cases, however, the high resistance made such a respirator impracticable.

The results, therefore, suggest the conclusion, which many members of the committee have reached as a result of practical experience, that respirators of the filter type cannot be expected to be highly efficient unless they are so impervious as to interfere very seriously with comfort and efficiency. They are excellent as a protection against occasional brief exposures, but we believe that it is not safe to rely on such respirators for routine use in continuous processes where there is exposure to dangerous materials.

Fortunately there is another type of respirator which is based on a wholly different principle and which can be made both efficient and comfortable. This is the respirator with positive air supply, bathing the face in fresh pure air and maintaining a constant outflow through the normal leakage spaces. Winslow, Greenburg and Reeves[14] have found this apparatus immeasurably superior to filter respirators for the protection of sandblasters. In some industries the use of such a device involves serious objections on account of the difficulty of securing positive air pressure, but in spray coating it is quite simple to obtain the air needed from the spray gun itself. Several devices of this kind are already on the market[15] and Commandant V. S. McKeon of the Mare Island Navy Yard has improvised one that has been used with marked success.

[14]Public Health Reports, March 5, 1920.

[15]See Appendix II, Figure 1 and Appendix II, Figure 2.

It is essential that the air supplied to the interior of the respirator should be kept free from oil vapors and other impurities. This may require the interposition of a purifier. It is also, of course, necessary to provide means of reducing the air pressure supplied to the mask.

We conclude that the positive pressure respirator is the type which should be recommended for the general protection of paint sprayers and are convinced that such a device if properly designed and operated will furnish an adequate and practical safeguard. Many other types of respirators have some value in reducing the lead hazard of workmen on non-continuous employment in spray painting.

XI. Medical Supervision of Spray Coaters

Wherever men are employed within buildings, booths or other indoor or enclosed spaces, in spray coating with materials containing benzol or lead in the form of paints, or silica in the form of vitreous enamel compounds, whether with or without exhaust ventilation or the use of respirators or masks, provision should be made for systematic routine medical examination for the detection of early symptoms of poisoning or of silicosis. For this purpose, we would suggest the following program:

Physical Examinations

(a) The health of persons inhaling material being sprayed upon interior surfaces may be injured by lead or benzol in paints or by finely divided siliceous materials in vitreous enamels. In order to protect spray operators from these hazards it is recommended that they be given a physical examination previous to or within one month of employment, in order to determine whether they have any physical defects which might be made worse by their employment and in order to obtain a record of their physical condition for comparison with succeeding examinations.

(b) Periodical examinations of persons spraying compounds containing lead or benzol upon interior surfaces should be made at least once every three months, and should include white and red blood cell counts and an estimation of the percentage of hemoglobin and of stippled cells in the case of lead exposure.

(c) The periodical examinations of persons spraying vitreous enamel or similar siliceous vitreous materials should be made at least once every year, and should include an X-ray examination of the chest.

(d) No person should perform the work of an interior spray painting operator with paints containing lead or benzol if the results of an examination of his blood show any evidence of a disturbance that would be aggravated by exposure to lead or benzol, or any evidence of lead or benzol absorption indicated by any of the following findings:

(1) The presence of twenty stippled cells per one hundred thousand.

(2) A distinct evidence of anemia as shown by hemoglobin under seventy per cent, or red blood cells under four million per cubic millimeter for men, and three million eight hundred thousand for women.

(3) A total white cell count under five thousand six hundred per cubic millimeter, or a total polymorphonuclear cell count under four thousand per cubic millimeter. When a second or succeeding differential count is more than five per cent lower in polymorphonuclear cells than the preceding one, the worker may be continued in his work for a period of no longer than three months if he seems to be in good physical condition otherwise. If, at the end of that period, a recount shows the condition to be progressive, he should not be permitted to continue spraying regardless of his physical condition in other respects.

(e) No person should spray vitreous enamel or other vitreous siliceous materials if an X-ray examination of his chest shows the presence of fibrosis or active tuberculosis. Any evidence of developing fibrosis at subsequent examinations should call for a change of occupation. Any evidence of progressive lead absorption by such persons, as indicated by the increase of stippled cells as described above, should likewise call for a change of occupation.

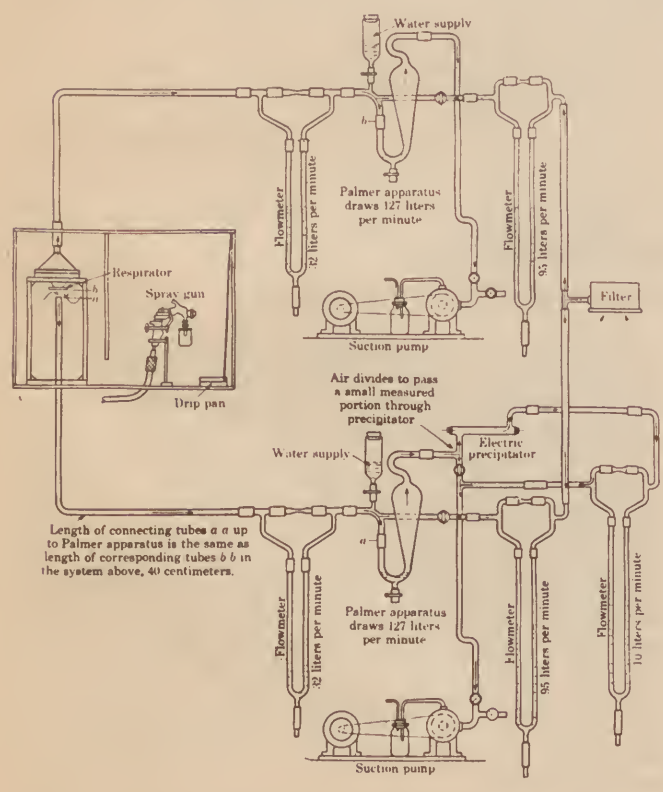

Figure 8. Diagram of the apparatus for testing respirators filtering water mist carrying silica dust.

XII. Fire Hazards

Study of the fire and possible explosion hazards introduced by the application of flammable materials by the spray method formed no part of the work assigned to this Committee. A few words on the subject, however, may not be amiss in a report dealing primarily with safety.

The existence of such hazards has been recognized for many years. These hazards can be adequately safeguarded by the proper storage and handling of finishing materials, properly designed and located non-combustible spray booths, adequate ventilation and good housekeeping, the safeguarding of electrical hazards and the elimination of open fires, unprotected flames and sparking or friction hazards and by proper fire protection. The most important of these safeguards are adequate ventilation and good housekeeping.

The precautions which should be taken are fully set forth in the National Fire Protection Association's pamphlet entitled "Pyroxylin Finishes—Their use and Suggestions for Safeguarding the Attendant Hazards" and the regulations of the National Board of Fire Underwriters for "Paint Spraying and Spray Booths." Copies may be obtained by writing to the National Fire Protection Association, 40 Central Street, Boston, Mass., or the National Board of Fire Underwriters, 85 John Street, New York City.

XIII. Elimination of Injurious Materials

If the foregoing conclusions are justified it is safe in indoor work to spray materials containing appreciable amounts of lead (over 2 per cent), benzol (over 1 per cent) or of free silica, when the worker is protected in one of the two following ways:

(a) By local ventilation producing an exhaust of 200 linear feet per minute in the breathing zone of the worker. This standard is not based on sufficient evidence to warrant its formulation as a legal requirement and subsequent study may show that a lower velocity may suffice with improved operating conditions.

(b) By an efficient mask or respirator, of the positive-pressure type.

In the case of all the three hazards considered there may often be a far simpler way out of the difficulty—to eliminate the substances in question from the materials used for spray coating.

Free Silica. The possibility of controlling the hazard of silicosis in vitreous enameling by the use of a properly balanced and completely fritted mixture free from soluble lead or free silica in substantial proportion, should be given careful study.

Benzol. In the case of benzol the conclusion seems clear that the presence of this substance in spray paints is entirely unnecessary. We have ourselves noted two plants using lacquer materials containing little or no benzol and entirely avoiding any suspicion of benzol poisoning. That relatively pure materials can be obtained is indicated by the fact that two samples of pure toluol obtained on the open market actually proved to be practically free from benzol. As a matter of fact, we have been informed that many lacquer manufacturers have seen the wisdom of discontinuing the use of benzol and of replacing it with non-poisonous toluol as the hydrocarbon thinner for nitrocellulose lacquers.

Lead in Interior Spray Paints. In so far as the spraying of interior surfaces with paints is concerned, it would appear that there is no necessity for using lead base spray paints for such purposes, as other materials are available which are entirely satisfactory in white and many light tints. In booth spraying of automobiles and similar fabricated articles, lead base paints could be eliminated in many instances but not entirely in automobile primers containing a moderate percentage of lead, or in the case of certain automobile chromate colors, for which satisfactory substitutes are not yet available. It is suggested that manufacturers experiment to find suitable colors to replace the lead pigments used in automobile undercoats.

Final Conclusion. We would then urge as our most important and fundamental recommendation that manufacturers of paints, lacquers, shellacs, varnished and vitreous enamels to be used in spray coating should so far as possible eliminate benzol, lead and free silica from their products and where this has been done should clearly label such products as containing less than a certain maximum amount of lead or benzol or free silica as the case may be; and that employers using the spray gun for indoor and booth work should so far as possible insist on obtaining and using only materials so labeled.

APPENDIX I

Summary of Findings in the Study of Spray Coating

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In estimating the industrial hazards of spray coating there are three principal problems to be considered, related respectively to the presence of benzol, of lead and of silica dust; and it will be convenient to report upon the data obtained in the National Safety Council study under those three respective heads.

I. Benzol

A. General Scope of Study

The plants selected for study in Detroit were those whose management had indicated to a local representative of the National Safety Council a willingness to cooperate in the survey. One Detroit plant and one in Toledo were added to the list as a result of a personal appeal of Dr. Smyth to their Medical Directors.

The contracting painters interviewed in Detroit were those whose cooperation was secured by local representatives of the Council or by direct solicitation.

The contracting painters interviewed in Toledo, as well as the enameling plants in Toledo and Cleveland were approached through one of the leading manufacturers of spray painting equipment. One other enameling plant was referred to us by a representative of the Ohio State Department of Health.

In the present study we have made tests in seven different plants employing lacquer sprayers more or less liable to exposure to the fumes of benzol. All of these were automobile or automobile body painting plants in which the car or body, usually mounted on a truck, stands in a booth which is really composed of a rear wall, a ceiling and sometimes a partial front wall. The gun pressure employed is generally 80-105 pounds. The exposure in an industry such as this is much more nearly continuous than is the case in house painting and in many other industrial processes. In our studies only seventeen men sprayed less than 50 per cent of their working time, twenty-two sprayed 75 per cent of their time, and sixteen sprayed over ninety per cent of their time, the average being well over seventy-five per cent.

A summary of conditions found in the automobile and auto body manufacturing plants is given as Table A.

As a rough indication of plant conditions as observed by the four members of our field staff, they were each asked to give a numerical rating of the plants in Detroit where studies of lacquer and undercoat spraying were made by them, with any special comment they cared to make. These ratings are given in the summaries of plant findings in Table A.

B. Atmospheric Conditions

All of the spraying booths studied were provided with exhaust ventilation and the efficiency of this ventilation was measured by measuring the velocity of the exhaust at one or more points at the face of the booth and near the level of the face of the operator. Measurements were made by the use of the kata thermometer[14], which gives the most accurate data in regard to low air velocities yielding values substantially higher than those obtained with the vane anemometer.

The average results of these air velocities at booths where lacquer was sprayed may be conveniently summarized as follows:*

Plant	1	2	4	5	6	17	18
Air Vel. Average	51	45	53	62	73	46	147**
Linear ft., Minimum per minute	30	0	31	38	54	10	0
Maximum	87	82	65	100	92	108	320

With the exception of Plant 18 the average figures are all in the neighborhood of 50-70 linear feet per minute. In Plant 18 the velocity averaged 147 linear feet, but at this plant the ventilating system had very recently been reconstructed and the conditions found are therefore not the same as those to which the workers had been exposed and which must have determined their physical condition as observed in our medical examinations. We may therefore for practical purposes assume that all the workers studied had been spraying with a protective exhaust ventilation corresponding to an average velocity of some 60 feet per minute.

Analytical Methods for Benzol

This part of the work was under the personal supervision of Dr. E. F. Pike and the methods described below were elaborated by him.

We may pass next to determinations of the benzol content of the atmosphere to which workers were exposed. The Committee on Benzol, Chemical and Rubber Sections, National Safety Council, in its work used a charcoal absorption method which is not specific for benzol but gives the total solvent vapors present in the air. This procedure was satisfactory in shops where benzol was the sole or the major constituent of the solvent vapor group which could be present. In spray coating however benzol is usually present in relatively smaller amounts and it was therefore essential in the present study to resort to a different procedure.

It was recognized early that the determination of benzol involved two distinct steps if a nitration method were to be adopted; first, complete nitration to a single compound, and, second, a 100 per cent determination of the nitro groups in that compound.

In the Pennsylvania investigation the benzol was determined by the procedure of Elliott and Dalton[15] which involves nitration, extraction with ether, reduction of dinitrobenzol with stannous chloride and titration of the excess of stannous chloride. This method proved unsatisfactory on account of large errors with high concentrations of benzol and in the present study the dinitrobenzol was titrated with titanous chloride. This procedure which proved reasonably satisfactory may be described as follows:

Sampling in the field was done with the portable apparatus shown in Figure 1.

The sampling nozzle A was usually suspended in a fixed place so as most nearly to approximate the average position of the sprayer's nose. At other times where wall painting was being done it was advisable to fasten the nozzle on a long stick, which was used to keep the nozzle continuously following the head of the worker as he moved about. Nozzle A was connected to the nitrating bottle B by means of acid cure rubber tubing that had been used previously for the passage of benzol-air mixtures. Bottle B had a ground glass cap as did the washing bottle G. Every effort was made to reduce the rubber connections to a minimum in the nitrating train. The air bubbles passed through the nitrating acid in a helical manner so that long contact was obtained between the bubble and the mixed acid. A mixture of one part fuming nitric acid Sp. gr. 1.50 and one part concentrated sulphuric acid Sp. gr. 1.83 was used. Red fuming nitric acid must not be used under any circumstances due to the practical impossibility of removing the dissolved oxides of nitrogen. It was necessary to discard several weeks' samples that had been made with red fuming nitric acid for this reason.

Bottle C is glass stoppered with entrance and exit tubes fused in, and is filled with 20 per cent caustic soda. This bottle prevents acid spray and nitric fumes from passing over into aspirating Bottle D.

Bottle D is calibrated in 100 c.c.'s of air as delivered through the system shown. It is absolutely necessary to carry out this calibration, using the entire nitrating and sampling train with the required volumes of acid and caustic soda in place.

The calibration is carried out using the apparatus shown in Figure 2, in the following manner:

[14] The Kata Thermometer: Its Value and Defects, W. J. McConnell and C. P. Yagloglou. Public Health Reports, U.S.P.H.S. Vol. 39, p. 2293, September 5, 1924.

[15] The Analyst, April, 1919, 44, No. 517, p. 132.

*Air velocities unless recorded as—indicate air movement away from the worker in direction of exhaust fan.

**Great variation in velocities in this plant.

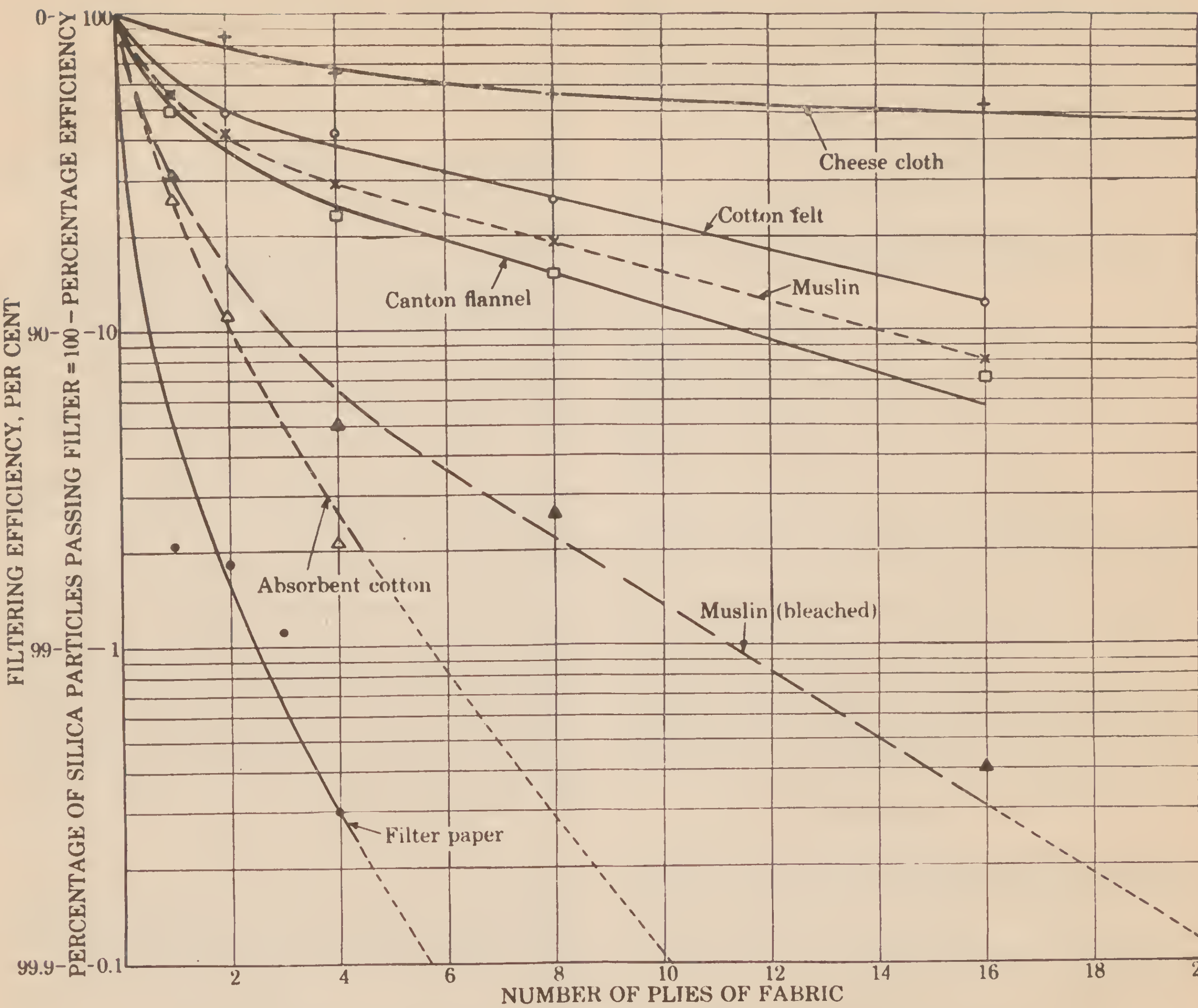

Figure 9 Efficiencies of various multiple fabric filters in filtering silica dust sprayed with water into air

A measured volume of water is poured in A. 1000 c.c. of water added here equal 500 c.c. of air displaced from B when equilibrium has been reestablished at atmospheric pressure. Acid bottle D and alkali wash bottle E contain the same amounts of liquids used in actual sampling practice. Water is allowed to siphon out of F, the bottle to be calibrated until the pressure in manometer C is atmospheric after each addition of water to A. The level of the water in F is marked after each addition. The bottle F is filled with water at the beginning to the calibration.

The samples of air taken averaged 2.5 liters. The rate of sampling was such as to give a continuous slow stream of bubbles through the acid.

After sampling in the field, the contents of B were emptied into a glass stoppered carrying bottle. The bottle was washed with several small portions of nitrating acid and these washings added to the carrying bottle.

Assuming the extraction methods to be satisfactory and the presence of meta-dinitrobenzene certain, the logical method of determination of the nitro groups is by some reduction scheme. The Elliott-Dalton method used stannous chloride. A more satisfactory method for the determination of nitro groups was found in the titanous chloride method. Some additions and slight modifications were made in adapting the method to the specific needs of our study.

Upon receipt of the samples at the laboratory, they were placed in a warm water bath to insure complete nitration. It was found unnecessary to do this, however, if the samples had been standing for several days before beginning the analysis. In all cases the samples were heated to 100° C. for an hour after removal from the carrying bottle to a 1000 c.c. beaker. This heating period was determined by passing a measured amount of benzol in a benzol-air mixture from the Yant-Frey apparatus[16] through the nitrating acid and heating for various periods to determine completion of nitration. The meta-dinitrobenzene was determined by weighing after crystallization.

Dilution of the sample was carried out by the addition of ice, which served to keep down the temperature.

The method for determining the benzol, which will be described in detail later, depends on the determination of the nitro groups in dinitrobenzol. It is, therefore, essential that no other compounds

[16] Yant, W. P., and Frey, F. E. Apparatus for preparing vapor-air mixtures of constant composition. Industrial and Engineering Chemistry, July, 1925, No. 7, p. 692.

containing nitro groups be present at the time of reduction with the titanous chloride. The possibilities for error in the use of the titanous chloride method may be looked for in (1) the nitration products of toluol; (2) alcohols, etc., with their oxidation products.

The solution after dilution was very carefully neutralized with sodium hydroxide and then made just barely alkaline. With care, some solid caustic can be used in the neutralization in order to keep the volume of the solution down to a minimum. The volumes usually extracted with ether were about 600 c.c.m.

The faintly alkaline solution is next distilled with steam. This removes the aliphatic alcohols, esters, etc., and their possible oxidation products which might be present in the original lacquer solvent. Some of the nitrotoluols, if present, would likewise be removed, while the slight alkalinity of the solution will prevent the removal of the dinitrobenzol due to the acidic character of dinitrobenzol.

The solution is next made slightly acid with HCl and extracted with ether. The ether must be neutral for this purpose. We employed a high speed stirring device for our extractions. The solution to be extracted was placed in a one-liter pear-shaped separatory funnel along with 50 c.c. of ether. The stirrer consisted of glass paddles fused to a glass rod and so arranged that the bottom pair forced the solution upward and the top pair forced the solution downward. In this way, rapid and complete extraction was obtained with four successive portions of ether.

There is little likelihood that the ether will extract more than a trace of the possible nitration products of toluol, such as para nitrobenzoic acid, if they were formed at all. It is entirely unlikely that the nitrobenzoic acids would be formed under the conditions of nitration outlined.

The ethereal extracts were added together and washed with a small amount of water. The ether is next evaporated in a water bath leaving the dinitro benzol.

The reduction of the dinitrobenzol follows very closely the original work of Knecht and Hibbert ("New Reduction Method in Volumetric Analysis," Longman's, Green & Company, 1918) and the subsequent work of F. L. English (J. I. & E. C. Vol. 12, No. 10, p. 924, Oct. 1920). The method depends upon the reduction of the nitro groups to amino groups by titanous chloride in a strongly acid boiling solution.

The details of the method are as follows:

Strength of Standard Solutions. As has been pointed out by previous investigators (English), a stronger solution of titanous chloride gives more accurate results. Throughout the larger part of our work the titanous chloride had an approximate strength of 0.25 N to 0.30 N.

Two other solutions were used, ferric alum at a normality of 0.05 and a ten per cent solution of NH_4CNS.

Preparation of Solutions. $TiCl_3$. Oxygen free water was used in the preparation of the titanous chloride solution. Distilled water was boiled for half an hour under reduced pressure and cooled in an atmosphere of hydrogen. The titanous chloride used was a 20 per cent solution. 167 c.c. of $TiCl_3$ and 150 c.c. HCl (sp. gr. 1.19) were boiled together and cooled under hydrogen. After cooling this mixture was added to the oxygen free water to make up a liter. It is advisable to prepare a large volume of the standard solution at one time and keep it in a dark colored bottle. Thorough mixture is assured by bubbling hydrogen through the liquid. The solution must be absolutely without sediment before it may be standardized.

Ferric Alum. 24.2 grams of c.p. ferric alum were dissolved in water acidified with 50 c.c. of 40 per cent sulphuric acid and the whole made up to a volume of one liter. This solution is stable and may be prepared in large volume. This solution must contain no ferrous iron.

The titanous chloride solution is placed in a dark colored bottle fitted with a three-hole stopper. The free space in the bottle is connected to a Kipp hydrogen generator so that it is always under pressure. A second glass tube reaching the bottom of the bottle serves as a siphon tube to the burette. The third tube connects the top of the burette with the space above the stock solution.

Sulphuric Acid. A stock solution of 40 per cent sulphuric acid facilitates the work where a large number of determinations must be made.

Carbon Dioxide. A constant and liberal supply of carbon dioxide is essential and is best obtained with a large size Kipp generator.

Titrations were carried out in wide mouth 250 c.c. Erlenmeyer flasks closed with three-hole rubber stoppers. These holes were for the entrance and exit of carbon dioxide and for the tip of the burette.

Standardization of Solution. The titanous chloride was standardized periodically against weighed amounts of pure, recrystallized m-dinitro benzol. The purity of the m-dinitro benzol was checked by its melting point.

A weighed amount of the dinitrobenzol was placed in the wide mouth Erlenmeyer flask and the least quantity of a mixture of equal parts of water and alcohol added to give complete solution. Using about 0.3 gm. samples of dinitrobenzol, the total volume of the solution in the flask was made up to 100 c.c. by the addition of water. Ten cubic contimeters of this solution were used for the standardization titration.

Twenty-five cubic centimeters of 40 per cent sulphuric acid were added and the flask was swept with a rapid current of carbon dioxide. Fifty cubic centimeters of the titanous chloride solution were added while the carbon dioxide current was continued.

The burette hole in the stopper was plugged with a glass rod and the solution was boiled for five minutes. The flask was cooled in a salt-ice mixture and then connected with the ferric alum burette and titrated until the violet color of the titanous solution had disappeared. Ten cubic centimeters of a 10 per cent solution of NH_4CNS were added and the titration continued until a permanent faint pink color was obtained. The carbon dioxide stream must be continued throughout the titration.

The determination of the samples taken in the field was carried out as follows: After evaporation of the ether, the material left in the flask was heated on the water bath to remove any possible oxidation products and then 5 c.c. of neutral, freshly distilled alcohol were added to facilitate solution. After standing on the water bath for a few minutes, 100 c.c. of oxygen free water were added and the flask again warmed. Aliquot portions of this solution were used for reduction by titanous chloride. Twenty-five centimeter portions were usually taken and the average of three titrations taken as the result.

An excess of titanous chloride was always used. With a little experience the operator can readily tell by the color of the solution when a sufficient excess of $TiCl_4$ is present.

Blanks were run regularly each day using the alcohol, water standard solutions, etc., that were used in the determinations, and the titanous chloride was checked daily against known amounts of meta-dinitrobenzol and the ferric alum solution.

The ferric alum did not vary but the titanous chloride solution did show considerable variation especially when it was exposed to strong sunlight in a light colored bottle.

Results of the Study of Benzol Concentration of the Air

Benzol determinations were made in all of the 27 plants studied but in two of them only red fuming nitric acid was available and these results were incorrect and had to be discarded. The data actually obtained are summarized in the table below. (For complete data see table B).

Plant		1	2	5	6	17
Benzol p.p.m.	Average	540	375	1035	872	1880
	Minimum	0	0	220	21	0
	Maximum	1140	1030	2200	3500	6500

The variations between different plants here recorded do not seem highly significant and, as will later be pointed out, they are not closely correlated either with the amount of benzol present in the lacquers sprayed or with the physical condition of the workers. We are forced to conclude that local variations in benzol content make the analyses of catch samples of air obtained in this way of very little significance. One thing only appears to be established by these analyses,—that the lacquer sprayer, even when using a lacquer of supposedly rather low benzol content and even with an average exhaust ventilation of 50-60 linear feet per minute may at times be exposed to very high concentrations of benzol, higher than those which the Committee on Benzol found associated with the blood picture of benzol poisoning in the rubber, artificial leather and sanitary can industries.

Distribution of Benzol Concentration in Air

	Total Analyses	Average	Number Ana yses Showing 0 p.p m	1–500 p.p m.	500–2000 p.p m.	Over 2000 p.p.m.
Pennsylvania	91	100	28	58	4	1
N. S. C.	85	918	5	36	33	11

It will be observed that the Pennsylvania studies yielded low benzol concentrations in comparison with the National Safety Council results. This is undoubtedly due to the fact that in Pennsylvania the spraying was done on small objects completely enclosed in booths and the exposure was very slight if ventilation was satisfactory.

It was impossible to make benzol determinations on all the materials sprayed but in Plant 18 the lacquer contained 1.5 per cent benzol; in Plant 17, 1.5% and 9%, and in Plant 1, 9 per cent. In Plants 4 and 5 and 6 low benzol lacquers were stated to be in use. Plant 2 was using four lacquers of differing benzol contents as shown in Table A. Concerning one of these lacquers we have no information, another contained less than ½% of benzol, the third contained 1½% of benzol and concerning the fourth we have no information other than the fact that the air analyses taken at points when this was being sprayed yielded high results.

It may seem surprising that we found so much benzol in the air where lacquers were being sprayed that are stated by the manufacturer to contain no benzol, but this may be explained by several factors. First, some lacquers now sold as free from benzol have only been so for a comparatively few months, and some old stock containing benzol is still in the market or on plant stock room shelves. Second, some plants do not use thinner supplied by the maker of the lacquer they are spraying but buy cheaper thinner containing benzol. Third, much of the two degree boiling range toluol used in lacquers may contain as much as or more than one-half of one per cent benzol, and denatured alcohols may also contain small amounts of benzol. A lacquer containing 0.5 per cent benzol has 5000 p.p.m. benzol, and when sprayed it may be diluted about 10 to 15 times with air, making the spray as it leaves the gun 300 to over 500 p.p.m. by volume benzol. In an actual test with a ½% benzol lacquer being sprayed we found between 200-300 p.p.m. of benzol as the spray left the gun. But in this instance the consumption of lacquer was much lower than is usually the case in automobile spraying.

C. Medical Findings

All of the data obtained for each individual sprayer examined are assembled in Table C, 1, 2, 3 and 4. The symptom complaints of all sprayers examined in the Pennsylvania Survey and the National Safety Council Survey are totalled and averaged by plant, by material sprayed and by length of service as sprayers in Table D, and are summarized in Table E.

Medical examinations were made on 160 different individuals in the seven lacquer spraying plants listed above, 2 sprayers in a custom finishing shop (No. 22) and 2 members of the survey staff who were directly exposed to lacquer fumes, including exhaustive case histories covering symptoms likely to be associated with industrial poisoning. Blood pressure records were made but in no case did they yield any data of significant value.

In field studies of this character one must be very cautious in making comparisons between plants on account of the many variables which cannot be controlled and which all have more or less influence on the results.

In addition to the quantity of material being sprayed and its toxic content the air pressure on the gun, the adjustment of the gun for liquid flow, the technic of the sprayer, the size and shape of the piece sprayed, the speed of work, the type of booth and arrangement and adjustment of baffles therein and the amount and direction and variation of room air currents all have a direct bearing on the results. With materials containing lead, the size of the lead particles in suspension and the specific gravity of the solvent are also important.

Unless most of the above conditions are determinable and comparable one is only justified in making broad general comparisons between groups of similar tests.

The histories of the 164 workers in question gave us a picture of 2.2 physical complaints reported per man, the most common being digestive disturbances, constipation, headache, nasal or post-nasal irritation, dyspnea and eye irritation. It is of some significance to note that the total of reported symptoms increases with length of service, the figures being 1.5 complaints per man for those employed for less than 6 months, 2.2 for those employed for 6 months to 2 years and 2.7 for those employed over 2 years.

The distribution of the more common or more significant symptoms by length of service is indicated in the table below.

Frequency of Complaints by Length of Service as Lacquer Sprayers

(Summarized from Table D)

	Per cent of workers reporting complaint: All lacquer sprayers	Under 6 months spraying	6 months to 2 years spraying	Over 2 years spraying
Eye irritation	28	26	25	32
Headache	18	13	16	23
Dizziness	18	10	14	26
Constipation	15	6	14	16
Digestive disturbance	13	6	11	17
Dyspnea	12	16	16	7
Loss of weight	12	6	11	17
Bleeding	8	0	13	6
Numbness	3	0	3	5
Tingling	3	3	3	5
Loss of appetite	10	10	14	6
Lead line	1	0	0	1
Gastric pain	0	0	0	0

It will be observed that every one of the complaints noted, tends to increase with length of exposure although dyspnea and bleeding fall off again in the workers with the maximum length of service. The latter phenomenon we attribute, as will be pointed out in connection with our blood findings, to a selective process which tends to eliminate from the industry all but individuals of a naturally high resistance to the influence of benzol.

For the purpose of analysis of our results we have divided the plants into two groups based on the degree of exposure to benzol. It appears obvious that when a lacquer is used which contains ittle or no benzol the exposure must be comparatively limited. On the other hand where high benzol lacquers are utilized the exposure may possibly, in the absence of adequate exhaust ventilation, be great. On this basis we have, therefore, grouped our plants into the so-called high and low exposure groups and we have, as will be seen later, made use of this classification in analyzng our results in the following pages.

The degree of exposure to benzol in these plants is indicated in the third column of the table on page 25, and given in somewhat greater detail in the summary of plant findings. In Plants 4 and 6 the lacquers used were very low in benzol content and in Plant 5 the men had recently been out on strike and had therefore not been extensively exposed to the hazards of the industry. We shall therefore call these three Low Exposure Plants and the other four High Exposure Plants. The Low Exposure Plants give an average of 1.2 complaints per man—the High Exposure Plants an average of 2.7 complaints.

Comparison of Low Exposure and High Exposure Plants gave no striking differences except in regard to constipation (6 and 19 per cent) dizziness (15 and 20 per cent) and dyspnea (6 and 17 per cent), the lower figure in each case referring to the low exposure plants.

D. Blood Findings. Special attention was of course paid to the blood picture since changes in the blood cells, particularly a reduction in white cell count, is the most characteristic index of very early benzol poisoning. We made determinations of hemoglobin content, color index, a red cell count and a differential white cell count.

Hemoglobin, and color index findings yielded no striking results, as was perhaps to be expected since the red cells are only affected in the later stages of benzol poisoning.

A red blood cell count below 4 million was found in 20 lacquer sprayers, the percentage incidence of such low counts being 7 per cent in the Low Exposure Plants and 17 per cent in the High Exposure Plants.

The white cell counts proved highly significant. Of the total group examined 11 per cent showed a total white cell count below the figure of 5625 fixed by the Committee on Benzol as indicative of clearly defined benzol poisoning.

In the course of the present study, blood findings were obtained for a series of 57 supposedly normal industrial workers. These were obtained from the records of the St. Joseph's Hospital of

Detroit, the industrial region in which our studies were conducted. The blood counts were selected from those records of blood examinations which we felt would be most nearly representative of the norm of the working population. Most of these studies represent the blood pictures of patients who entered the hospital after less severe types of street accidents without severe hemorrhage. These yielded even higher total white cell counts than did the Pennsylvania normals, but a rather decidedly lower red cell count (see Table F) so that we have taken the normal red cell count in our National Safety Council studies as 4,500,000 rather than 5,000,000 and in both instances (National Safety Council and Pennsylvania studies) we have taken 9,000 as our normal for white cells. The usual text-book average is 7,500 and the Committee on Benzol took a 25% reduction below this 7,500 value as indicating a definitely significant decrease. It would appear that the normal average for industrial workers in the districts studied should be placed at 9,000 instead of 7,500, attributing the higher value to general prevalence of catarrhal inflammations of the upper respiratory tract, of pyorrheal conditions and of venereal disease. For the purpose of the present discussion, however, we have felt it wisest to retain the 5,625 standard as an index of benzol poisoning, for comparability with the work of the Committee on Benzol and in order to be very conservative in the interpretation of our findings. It will be apparent that even on this basis our results are sufficiently significant.

The table below shows the distribution of white cell counts in the group of 160 lacquer sprayers by length of service as sprayers.

Relation Between Total White Cell Count and Count of Polymorphonuclear Leucocytes

(Summarized from Table C 1)

Polymorphonuclear Count	Total White Count 4000–4999	5000–5999	6000–6999	7000–7999	Over 8000
1000–1999	1	1	0	0	0
2000–2999	4	2	3	0	1
3000–3999	1	15	18	3	7
4000–4999	0	2	14	19	17
5000 and over	0	0	0	3	49

As in the case of the total white cell count the number of polymorphonuclear leucocytes fall off with increasing length of service as indicated below.

Distribution of Polymorphonuclear Leucocyte Counts Among Lacquer Sprayers by Length of Service as Sprayers

(Summarized from Table H)

Length of Service	Number Sprayers	Percentage of Sprayers Showing Counts Below 2000	2000–2999	3000–3999	4000–4999	5000 and over
Up to 6 mo.	31	0	4	16	32	48
6 mo. to 2 yr.	63	0	8	34	25	33
Over 2 yr.	66	2	8	26	38	26
TOTAL	160	1	6	27	32	34

We also note the same marked excess of low counts in the High Exposure Plants as compared with the Low Exposure Plants.

Distribution of White Cell Counts Among Lacquer Sprayers by Length of Service

(Summarized from Table G)

Length of Service	Number Sprayers	Percentage of Sprayers Showing Counts Below 5000	5000–5999	6000–6999	7000–7999	8000 and over
Up to 6 mo.	31	0	10	20	10	60
6 mo. to 2 yr.	63	2	16	22	11	49
Over 2 yr.	66	8	11	23	23	35
TOTAL	160	4	12	21	15	48

The relation of the average total white cell count by length of service as shown in Figure 3,—for both the Pennsylvania and the National Safety Council studies—brings out some very interesting points. It will be noted that the National Safety Council averages are throughout very much lower than the Pennsylvania figures, as one would expect from the much greater exposure in the latter case. In both curves we note the preliminary stimulation (noted in the report of the Committee on Benzol) followed by a gradual fall to the period of 6 years. After six years the average figure rises again as a result of a process of selection which has weeded out all but the most resistant workers.

The difference between our Low Exposure Plants and our High Exposure Plants is very striking, as indicated in the table below.

Distribution of White Cell Counts Among Lacquer Sprayers According to Exposure

(Summarized from Table C 1)

	Percentage of Sprayers Showing Counts Below 5000	5000–5999	6000–6999	7000–7999	8000 and over
Low Exposure Plants	0	1	10	21	68
High Exposure Plants	8	19	31	11	31

In addition to the total white counts differential counts were also made of the various types of white blood cells, but while these proved of considerable theoretical importance they added nothing to our practical differentiation between good and bad conditions. The table below indicates that the number of polymorphonuclear leucocytes followed closely the distribution of the total white cells although falling off somewhat less sharply. There are more instances, in other words, of low total white count with fairly high polymorphonuclear count than of the opposite combination. Both the total white count and the polymorphonuclear count seem to be very delicate indices of early benzol poisoning.

Distribution of Polymorphonuclear Leucocyte Counts Among Lacquer Sprayers According to Exposure

(Summarized from Table C 1)

	Percentage of Sprayers Showing Counts Below 2000	2000–2999	3000–3999	4000–4999	5000 and over
Low Exposure Plants	0	1	18	31	50
High Exposure Plants	2	10	33	33	22

E. General Summary of Benzol Findings

Finally, it remains to discuss the individual cases in which the complex of symptomatology and blood findings makes it reasonably possible to make a probable diagnosis of benzol absorption or poisoning.

Plants 4 and 6 gave us no cases at all of this kind. These were the two plants which sprayed materials stated to contain little benzol.

Plant 5 was using a benzol lacquer in some cases, but the men had only just re-commenced work after a strike and had therefore been free from exposure for a period of 5 weeks prior to our studies. Here one man (No. 155) showed a white cell count of 5550 and polymorphonuclear count of 3330. He showed also loss of weight and complained of dizziness.

Thus of 69 men in the Low Exposure Plants there was but one individual showing a picture at all suggestive of benzol absorption.

Plant No. 2 used four different lacquers, the benzol content of which has been previously discussed. Eight of the men showed low red counts and nine showed low white counts, while two gave fairly clear pictures of benzol poisoning. One of those men (No. 41) had a total white count of 4050 and a polymorphonuclear count of 2146. He showed loss of weight and post-nasal irritation and complained of digestive disturbances, constipation, dizziness, dyspnea, and numbness of the extremities. The second (No. 72) had a red cell count of 3 million, a total white count of 5550, a

polymorphonuclear count of 2830. He showed loss of weight, and complained of poor appetite, digestive disturbances, dyspnea and dizziness. These are both fairly clear cases.

Plant 18 used a lacquer containing 1.5% benzol. Four out of 11 men showed low white counts and one of these (No. 291), with a total white count of 5400 and a polymorphonuclear count of 3834, reported nose bleed and numb fingers, suggestive at least of benzol absorption.

Plant 17 used lacquers containing respectively 1.5% and 9% of benzol. Three out of 16 men showed low red counts and 2 low white counts, both of the latter with other suspicious symptoms. One worker (No. 264) had a red count of 3,900,000, a total white count of 5350, and a polymorphonuclear count of 3977. He complained of headache and tingling of the extremities. The second man (No. 268) had a high total white count (8450) but his polymorphonuclear count was low and he showed loss of weight and complained of loss of weight, poor appetite, digestive disturbances, headache, dizziness, nasal bleeding, eye irritation and tingling of the hands.

Finally, in Plant 1 using a lacquer containing 9% benzol there were four out of 23 men with low blood counts and two with general symptoms. The first (No. 12) had 4,900,000 red cells and 5150 white cells, with 3090 polymorphonuclear leucocytes. He complained of loss of weight, poor appetite, headache, dyspnea and eye irritation. The second (No. 13) had 4,400,000 red cells and 5950 white cells, with 3690 polymorphonuclear leucocytes. He suffered from loss of weight, poor appetite, constipation, headache, dizziness, dyspnea and postnasal irritation.

Thus of 91 men in the High Exposure Plants 7 gave more or less suggestive clinical pictures of early benzol poisoning. The table below gives a general picture of the situation.

A number of other contracting painters were interviewed but their employees were not examined as their time was divided irregularly between spraying and brush painting.

In almost all instances it was possible to determine the presence of lead in the spraying materials by the methods described below.

In 5 plants spraying undercoats the lead was constantly present to the amount of 10 per cent in three cases, eleven per cent in the fourth case and 19 per cent in the fifth case. The paint employed by the two groups of indoor wall sprayers (3 and 12) contained .002 and 0.5 per cent of lead respectively, while the paint used by the group of outdoor sprayers (11) had 19 per cent. The percentage of soluble lead in the vitreous enamels varied widely as follows: (Plant 7, 0.4%; Plant 8, 20%; Plant 9, 14%; Plant 19, 4%; Plant 28, 11%; Plant 29, no data). Detailed results of these analyses are to be found in tables I and J.

B. Atmospheric Conditions

In Plants 2, 4, 5, 6, 17 and 18 spraying was performed in booths similar to those described above for lacquer spraying and the efficiency of the exhaust ventilation provided was measured as in the former case by the use of the kata thermometer. The values obtained in 39 such measurements were as indicated below:

In the booths used for spraying paints and undercoats the average exhaust velocity is between 28 and 75 linear feet per minute except in the case of Plant 6 where the only two determinations made showed 160 feet. Velocities in the vitreous enamel plants were distinctly higher. "Plants" 3 and 12 were not really plants at all but groups of interior painters using the spray gun in rooms where the air velocity was below a measurable figure, while "Plant" 11 was a group of exterior painters operating outdoors in a strong current of air (two observations, each of 300 feet).

Final Analysis of Blood Counts, Complaints and Per Cent of Cases Showing Benzol Poisoning or Absorption by Plants.

(Summarized from Table C 1)

Plant No.	No. Men	Exposure	Average Length of Service Yrs.	Per Cent of Counts R.B.C. Below 4 million	Per Cent of Counts W.B.C. Below 5625	Average Complaints per man	Per Cent Cases of Benzol Poisoning or Absorption
4	17	low*	3.7	12	0	2.1	0
6	27	low*	1.8	0	0	1.2	0
5	25	low#	1.9	12	4	2.2	0
2	41	variable◈	2.5	20	21	2.4	5
18	11	high xx	1.8	9	36	1.6	9
17	16	high xx	1.6	19	12	1.6	12
1	23	high xx	2.1	18	18	4.4	9
TOTAL	160	....	2.3	12	11	2.2	5

*Compounds sprayed stated to contain little benzol.

#Men had been on strike and had had time to recover from previous exposure.

xxLacquer sprayed contained 1.5 to 9% benzol.

◈But probably high.

It seems evident that the application with the spray gun of lacquers containing benzol involves a hazard which is of very real importance. Out of 69 men in the Low Exposure Plants only 1 individual showed a white cell count below 5625 and only this man reported a symptom complex at all suggestive of benzol poisoning. Among the 91 men in High Exposure Plants on the other hand 18 or 20 per cent showed a white cell count below 5625 (compared with 32 per cent reported by the Committee on Benzol for rubber and artificial leather and sanitary can manufacture) and 8 per cent gave a symptom complex strongly suggestive of benzol poisoning.

II. Lead

A. General Scope of Study

In the present study we were able to conduct studies in six different automobile or automobile body plants spraying paints and undercoats containing lead (6 of the 7 plants in which benzol sprayers were studied) and three groups of employees of contracting painters, using the spray gun with lead paints on inside and outside work. In addition we studied 5 groups of sprayers applying lead containing vitreous enamel to castings. A total of 172 men were given a comprehensive medical examination and tests for lead in feces (urine tests were omitted) and blood examinations were made on a number of these as indicated in tables C 2, K and L. Table C 2 also describes previous occupations where they were of any significance.

We may pass next to determination of lead in the air espiredr by the worker. All in all 42 analyses of this kind were made. Air samples were collected by the use of the Greenburg-Smith impinger in the vitreous enamel plants while in the undercoat tests the lead was collected by aspirating the air through a well-packed 2 inch cotton filter. See Table I.

The chemical analyses of samples for lead were conducted by H. F. Smyth, Jr., the methods used for the estimation were the same as those used in the Pennsylvania studies and were selected after conference with members of the Staff of the U. S. Bureau of Mines, these were as follows:

Observed Air Velocities Associated with the Spraying of Undercoats, Wall Painting and Vitreous Enamels

(Summarized from Table A and Table I)

Industry	Spraying Undercoats						House Painters		
Plant or Employer	2	4	5	6	17	18	3	11	12
Air Vel. Average	75	54	52	160	28	..	0	300	0
Ft. per Minimum	49	49	46	160	8	..	0	300	0
Minute Maximum	140	64	65	160	43	..	0	300	0

Vitreous Enamels

Industry						
Plant	7	8	9	19	28	29
Air Vel. Average	130	123	...	212	...	116
Ft. per Minimum	130	111	...	166	...	97
Minute Maximum	130	136	...	257	...	128

Chemical Methods Used in Lead Determinations

A. Preparation of Sample

Feces specimens were collected in Atlas flint glass wide mouth jars, provided with glass lids and rubber rings. In no case was material which had touched the rubber used in the analyses. Since the samples were to be weighed very soon after collection, no preservative was added. Forty gram samples were weighed out in Coors porcelain crucibles (in some cases the entire sample collected was less than forty grams). The feces was dried in an air bath for about twenty hours, and then ashed in an electric muffle kept at a temperature judged to be 600°C. The ash was allowed to cool, was then warmed with one to one HCl, and filtered through ashless paper. The residue was washed and the paper ashed. This second ash was extracted with ten per cent tartaric acid in one to one HCl, and filtered. The filtrate from this was added to the first filtrate. The combined filtrates were made alkaline with NaOH, then made just acid to methyl orange with HCl, allowed to stand one-half hour, and the reaction again adjusted.

Dust samples collected on cotton filters were ashed in the muffle and the ash extracted with warm one to one HCl. The solution obtained was made slightly alkaline, and then just acid to methyl orange with HCl, allowed to stand, and the reaction readjusted.

Paint samples were weighed out into Coors crucibles, ashed, the ash extracted with one to one HCl, and the entire ash suspended in the extract. This was brought to the proper acidity as above.

Enamel samples (vitreous) were warmed with one to one HCl and the entire sample suspended in the extract, which was brought to the proper acidity as above.

B. Determination of Lead

The solutions obtained above were saturated with H_2S and allowed to stand at least three hours under an atmosphere of H_2S. They were then filtered, washed with water saturated with hydrogen sulphide and containing 0.1 per cent HCl. The sulphide on the filter was dissolved in hot one to one nitric acid, the filter paper washed into the filtrate, which was then evaporated to a small bulk to coagulate the sulphur. This was then diluted and sulphur filtered off, the solution cooled, thymol blue added, then enough strong NaOH solution to turn it a faint blue. Acetic acid was added to a pale green, then 3 c.c. in excess, 10 c.c. of 10 per cent sodium chromate was added, and the solution brought nearly to boiling. It was allowed to stand over night, then it was filtered through asbestos, washed with hot water, very thoroughly.

The lead chromate on the asbestos was dissolved in ten per cent HCl, the filter was washed well into a Nessler tube, and 2 c.c. of a one per cent s-diphenyl carbizide solution in glacial acetic acid was added. The volume was made up to the mark, and after standing two minutes, the color developed was compared with a series of tubes made up from a known lead chromate solution (in HCl). It was usually necessary to compare the color of an aliquot part of the solution, due to the deep color developed by large amounts of lead.

All reagents used were previously tested for lead. Frequent blanks were run, using the same amounts of reagents. These blanks were consistently zero. New Pyrex glassware was used throughout. All porcelain was new Coors. No other work with lead was being done in the same building.

Lead Findings (See Table I)

Of the five undercoat plants studied, two (Plants 2 and 6) gave values of 0.2 mg. of lead per cubic meter of air, well below the danger limit which may be set at about 0.6 mg. The other three plants gave very high average figures (Plant 4, 32 mg.; Plant 17, 99 mg. and Plant 5,164 mg.). The air in the vicinity of the indoor wall painters (Plants 3 and 12) was negative for lead. The air in the vicinity of the outdoor painters (Plant 11) using a paint of very high lead-content, but in a strong air current, gave 1.0 mg. per cubic meter, a possibly significant amount. It should be noted that the air samples examined were of from 2 to 12 liters each and that only from 1 to 8 samples were taken in each plant. The opportunity for chance errors is therefore very great and the results for an individual plant may not be truly representative of existing conditions.

In anlayzing the air tests for lead it was noted that the air pressure at the gun on the fluid being sprayed had a decided influence on the amount of lead in suspension in the air sampled. No negative results were obtained with gun pressures of over 95 pounds while only two out of six tests with pressures under 90 pounds were positive, one of these being the minimum amount detected by the method employed. These results are given in Table M.

C. Medical Findings (See Table C 2 and C 4)

Before proceeding to a discussion of our medical findings it will be well to consider first of all results of feces examinations as evidence of the ingestions (though not necessarily of the absorption) of lead. Fifty-five examinations of this type were made with the results indicated below, as compared with the findings of the committee appointed by the Surgeon-General of the U. S. Public Health Service [17], to study the hazards involved in the use of tetraethyl lead gasoline.

Per Cent of Individuals Showing Specified Milligrams per Gram of Feces

	Under .0001–.0003	.003–.01	.01–.03	.03–.1	.1–.3
Normals*	52	45	2	0	..
Spray coaters	65	3	15	15	2
Lead-trade #	5	27	34	32	2

*U. S. Public Health Service, Groups A and B, 77 Automobile Drivers.
#U. S. Public Health Service, Group E, 43 individuals in highly hazardous lead industry.

It will be noted that our spray coaters fall midway between the normals and the highly intensive lead hazards studied by the Public Health Service.

Medical examinations were made on a total of 170 persons, including 97 undercoat sprayers, 38 house painters and 35 vitreous enamel sprayers.

The histories of these men showed 1.8 complaints reported pes man, slightly less than the figure of 2.2 reported by the lacquer sprayers. Analyzed by length of service, we find .8 complaintr per man in the group employed less than 6 months, 2.1 complaints per man in the group employed 6 months to 2 years and 2.2 complaints per man in the group employed over 2 years. (See Table E.)

The incidence of the more significant symptoms by length of service is indicated in the table below for the entire group spraying lead, whether undercoat sprayers, house painters, or vitreous enamel sprayers.

Frequency of Complaints by Length of Service as Sprayers

Per cent of workers reporting complaint. (See Table D)

	All lead sprayers*	Under 6 mo. service	6 mo. to 2 years service	Over 2 years service
Eye Irritation	19	17	13	25
Headache	18	8	16	23
Dizziness	17	3	18	23
Constipation	9	3	12	10
Digestive Dist.	19	6	24	20
Dyspnea	10	6	13	10
Loss of weight	10	3	10	13
Bleeding	4	0	4	6
Numbness	1	0	3	0
Tingling	7	3	7	9
Loss of appetite	8	6	10	8
Gastric pain	3	0	4	4
Lead line	5	3	7	3

*Includes all undercoats, paints and vitreous enamel sprayers.

Of the 13 complaints listed, only 6 (constipation, digestive disturbances, loss of weight, loss of appetite, gastric pain and the lead line) are of special significance in relation to lead poisoning. As in the case of the lacquer sprayers we note that, with the exception of eye irritation, the incidence of every symptom recorded increases with length of service when we compare the group employed for less than 2 months with the group employed for 6 months to 2 years; while, as in the case of the lacquer sprayers, the incidence of many symptoms decreases again in the group employed for over 2 years, as a result of natural selection. Some of these men at times sprayed lacquer and some at times sprayed undercoats containing benzol.

[17] The Use of Tetraethyl Lead Gasoline in Its Relation to Public Health. Public Health Bulletin No. 163, Treasury Department, Washington, D. C., 1926.

In comparing the total incidence of symptoms among lead sprayers with that among benzol sprayers (see page 8) it appears that the lead sprayers show more digestive disturbance, gastric pain and lead line while the benzol sprayers show more eye irritation and nasal bleeding. Constipation is also somewhat more frequent among the benzol sprayers. (See Table D.)

D. Blood Findings (See Tables C 2 and C 4)

In the case of the workers exposed to lead determinations were made, so far as circumstances permitted, not only of hemoglobin, color index, total red cells and differential white cells, but also of the specific indices of lead poisoning furnished by the observation of stippled cells.

The hemoglobin and color index results were slightly lower than those recorded for the lacquer sprayers, but the differences were not sufficient to be considered of any substantial significance.

Of the total of 170 men examined, 25 or 14% showed a red blood cell count below 4 million as against 12% for the group of lacquer sprayers, while only 5 or 3% showed a total white cell count below 5625, as against 11% of the lacquer sprayers. Analysis of red blood cell counts by length of service shows that of men employed less than 6 months 18% had counts below 4 million as did 7% of men employed for 6 months to 2 years and 38% of men employed over 2 years.

As an evidence of the absorption of lead we made determinations of the stipple cell count of the blood of a representative group of the workers whom we examined. In order to do this we selected a random group of 50 blood slides of workers in several of the plants under investigation. In the case of only 31 of these workers, however, do we have information regarding the lead content of the material with which they were engaged in their occupation. Fifteen of these lacquer sprayers worked with materials containing little or no lead and the remaining 16 workers engaged on undercoats and vitreous enamels worked with materials containing large amounts of lead. The results of these blood studies are shown in the following table:

Stippled Blood Cell Counts

Workers No.	Material Sprayed	Plant No.	% of Lead in Material	Stippled Cells per 100,000 R.B.C.
200	Lacquer	6	.19	25
201	Lacquer	..	.19	33
202	Lacquer	..	.19	25
204	Lacquer	..	.19	50
206	Lacquer	..	.19	28
208	Lacquer	..	...	0
209	Lacquer	..	.19	50
210	Lacquer	..	.19	50
211	Lacquer	..	...	0
212	Lacquer	..	.19	25
213	Lacquer	..	.19	163
214	Lacquer	..	...	0
215	Lacquer	..	...	0
216	Lacquer	..	...	0
217	Lacquer	..	...	0
218	V. E. Castings	7	.4 to .7	160
219	V. E. Stampings	7	.7	66
220	V. E. castings & stamp	7	.7	0
221	V. E. castings & stamp	7	.4 to .7	0
224	V. E. Castings	7	.4	0
226	V. E. Castings	7	.20	909
227	V. E. Castings	7	.20	400
229	V. E. castings & stamp	8	.20	366
233	V. E. Stampings	8	0	0
236	V. E. stampings & cast	8	.20	225
238	V. E. stampings & cast	8	.14	28
239	V. E. stampings & cast	9	.14	218
242	V. E. Stampings	9	0	85
243	V. E. Stampings	9	0	25
244	V. E. Stampings	9	0	0
245	V. E. Castings	9	.14	571

The results of these stipple cell studies presented in the table below (as compared with data from the tetra-ethyl lead report) indicate the existence of a very real hazard.

Distribution of Stippled Cell Counts

Groups	Number of men grouped according to Stippled Cell counts per 100,000 red cells. Below 20	21–100	100 plus
Normals*	112	1	0
Lacquer Sprayers	7	7	1
High Lead Hazard#	26	16	19
Lead Sprayers	5	6	7

*U. S. Public Health Service, Groups A and B, Automobile Drivers.
#U. S. Public Health Service, Lead Workers.

E. General Summary of Lead Findings

We may next consider the individual cases showing a complex of symptoms suggestive of lead poisoning.

In the six groups of undercoat sprayers, including 97 workers, we found 6 cases of this type of 6%. Plants 4, 5, 6 and 17 gave us no individuals of this type in spite of the fact that all four of them used materials containing 10-19% lead. A large proportion of the men showed lead in the feces and Plants 4 and 5 many blood tests were positive; but there was no case manifesting both positive blood findings and diagnostic signs.

In Plant 18 one man out of 9 employed (No. 293) showed a red blood count of 3,600,000 and complained of dizziness and dyspnea. This may be regarded as perhaps a suspicious case.

In Plant 2 we found our chief group of cases. This was an automobile body plant using a paint containing 10% lead. Here, out of 14 men employed, 5 showed what appeared to us to be a significant symptom complex.

No. 44 had a red count of 4,600,000. He had a blue line on the gums and complained of dizziness, constipation and gastric pain.

No. 47 had a red count of 3,200,000. He had a blue line on the gums and complained of loss of weight, poor appetite and digestive disturbance.

No. 55 had a red count of 4,800,000. He showed the blue line and complained of constipation and dizziness.

No. 59 had a red count of 3,900,000. He complained of loss of weight, headache and tingling of the extremities.

Of the three groups of house painters, including 38 individuals, 3 presented the following complexes of symptoms suggestive of lead poisoning:

No. 248 (Employer No. 11) had a red count of 4,300,000. He complained of loss of weight, constipation, headache and dizziness.

No. 334 (Employer No. 26) had a red count of 5,400,000. He had a definite clinical history of lead colic.

No. 338 (Employer No. 27) had a red cell count of 6,000,000 but complained of digestive disturbances and had a history of recent lead colic.

Of the 6 groups of vitreous enamel workers spraying lead, including 37 individuals, 5 showed significant symptoms as follows:

No. 218 (Plant 7) had a red count of 4,300,000 with stippled cells. He showed marked pallor and complained of digestive disturbances, constipation, dizziness and dyspnea.

No. 227 (Plant 8) had a red count of 4,400,000 with stippled cells. He complained of poor appetite, digestive disturbances and headache and gastric pain.

No. 342 (Plant 28) had a red count of 3,800,000. He complained of dizziness.

No. 351 (Plant 28) had a red count of 3,800,000 but no clinical symptoms.

Summary of Findings in Regard to Lead Sprayers—Percentage of Workers in Each Group

Industry	No. men	Average length service years	Lead in feces over .01 mg.	R.B.C. % below 4 m.	W.B.C. % below 5625	Average complaints per man	Per Cent showing blue line	Per cent cases of probable plumbism
Spraying Undercoats	97	2.1	24	18	3	1.7	10	6
House Painting	38	2.5	33	13	3	1.4	0	8
Spraying Vitreous Enamels	35	2.2	57	9	3	2.6	3	14
TOTAL	170	2.3	32	14	3	1.8	6	8

No. 353 (Plant 28) had a red count of 3,800,000. He showed the blue line and complained of loss of weight, poor appetite digestive disturbances, constipation, dizziness and tingling of the extremities.

The table below gives a general picture of our findings in the 3 groups of workers spraying lead. It will be noted that the average length of service is the same as that of the group of lacquer sprayers, 2.3 years. Both groups show about the same proportion of workers with low red cell counts (12 and 14% respectively), Neither figure being high enough to be of marked significance. The proportion of low white counts is, as would be expected, much less among the lead sprayers (3% as against 11%). On the other hand the porportion of individuals showing a complex of symptoms suggestive of definite lead poisoning (8%) is higher than in the case of benzol (5%).

III. Silica

A. General Scope of Study

In the present study we included 10 different groups of workers, 6 groups (Plants 7, 8, 9, 19, 28 and 29) spraying vitreous enamel on castings and 4 groups (Plants 7, 8, 9 and 28) spraying vitreous enamel on sheet metal. The first group included 35 workers, of whom 2 were women; the second group, 26 workers of whom 19 were women. For more detailed information concerning the occupational conditions see table C 3 and 4 and Table P.

Method Used in Silica Determination

Samples of vitreous enamels were dried to constant weight at 105°, ground in an agate mortar, and half gram portions weighed from them.

These portions were digested with concentrated HCl on the water bath until decomposed, that is until no more hard particles could be felt with a stirring rod. They were then evaporated to dryness five times on the water bath with concentrated HCl, and then baked fifteen minutes at 120°.

The residues were taken up with hot water, filtered through ashless paper, washed with hot water. The paper was dried, ignited, and weighed.

The weighed ash was moistened with water, in a platinum crucible, a few drops of sulphuric acid and ten c.c. of hydrofluoric acid were added, and the crucible placed on the water bath It was evaporated nearly to dryness, then carefully dried over a bunsen burner, and finally ignited. The weight of material now left in the crucible represented impurities in the silica, and was deducted from the weight of ash as originally determined. Percentage silica was calculated as to the nearest tenth per cent.

As a rule the enamels sprayed on castings include a substantial proportion of lead while the enamels sprayed on sheet metal are generally free from lead but contain a very high percentage of silica. The situation as we found it is indicated in the table below.

Composition of Vitreous Enamels

(See Table J)

Plant	Castings % Lead Total	Castings % Lead Soluble	Castings % Silica	Sheet Metal % Lead	Sheet Metal % Silica
7	26	0.4	21	3	43
8	23	20	26	0	45
9	15	14	24	0	47
19	4	4	37	..	..
28	13	11	34	0	43
29	..	..	..	..	..

We have, then, two very distinct groups of workers, sprayers on castings (practically all men) with a high lead exposure and a moderately high silica exposure and sprayers on sheet metal (mostly women) with little or no lead exposure and a very high exposure to silica. Many of our findings with regard to the sprayers on castings have already been discussed under the general subject of lead hazards and the 35 workers in this group are included in all our lead statistics above. It remains to discuss the special dangers incident to the spraying of the enamel itself as distinct from the factor of lead exposure.

B. Atmospheric Conditions

We have already cited on page 25 our air velocity data for spraying on castings in Plants 7, 8 and 19. These data are repeated below for comparison with figures for booths where sheet metal was sprayed in the same plants.

(See Table P)

Material Sprayed	Castings			Sheet Metal		
Plant	7	8	19	7	8	9
Air Vol. Average	130	123	212	84	125	0*
Air Vol. Minimum	130	111	166	30	74	0*
Air Vol. Maximum	130	136	257	142	240	0*

*Too low to be measurable.

We may pass next to determination of dust particles in the air, the most important analytical figure in determining the extent of the hazard to which vitreous enamelers are exposed. In all 33 tests for dust particles were made in the vitreous enamel plante by the use of the Greenburg-Smith impinger.

The results obtained, classified by plants and according to the type of spraying performed are presented in the table below. The results are striking and highly significant.

Comparison of the two preceding tables shows that Plant 19 the only one equipped with a ventilation system capable of producing an average exhaust of over 200 linear feet per minute, gave

Dust Content of the Air at Vitreous Enamel Booths

Millions of Dust Particles (¼ standard unit size) Per Cubic Foot of Air (Summarized from Table N)

	Castings					Sheet			
Plant	7	8	19	28	29	7	8	9	28
Average	24	5	0.4	2	1.2	18	11	445	30
Minimum	23	5	0.3	2	.7	9	4	100	27
Maximum	25	6	0.5	2	1.6	27	20	1800	34

General Summary of Blood Tests and Medical Findings

(See Table D)

Type of Spraying	No. Men	Average Service Years	R.B.C. % below 4 m.	W.B.C. % below 5625	Complaints average per man
On Castings	35	2.2	9	3	2.6
On Sheet Metal	26	2.1	12	0	3.0
Total V. E.	61	2.2	10	1	2.8
Undercoats & Paints	135	2.2	17	3	1.6
Lacquers	160	..	12	11	2.2

us an average dust count of 400,000 particles per cubic foot. Plants 7 and 8, with exhaust velocities between 80 and 130 feet gave dust counts of between 6,000,000 and 27,000,000 while Plant 9 with an exhaust system too poor to produce a measurable velocity gave an average of 445,000,000 particles per cubic foot. For Plants 28 and 29 (castings) and for Plant 28 (sheet metal) we have unfortunately no air measurements.

C. Medical Findings and Blood Examinations

The blood findings are not of particular significance in regard to the silicosis hazard and with the general results of the medical examinations may be summarized in the table below, for the two groups of vitreous enamel sprayers, with the group of 135 undercoat sprayers and house painters and the groups of 160 lacquer sprayers for comparison.

The vitreous enamel sprayers, as might be expected, show only 1% of those examined with a white cell count below 5625, for there is no special benzol hazard in this group. The red cell counts are again not particularly significant and it would appear that some 10% of any average group of workers may show a red count falling below the 4 million line. The complaints reported by the workers were higher among the vitreous enamel sprayers than among the other groups studied. In the case of the sprayers on castings this is probably due to the double exposure to both lead and silica. In the case of the sprayers on sheet metal (with only the silica hazard) the still higher rates of complaints are no doubt due to the fact that we are here dealing with a group composed mainly of women.

The analysis of certain specifically important symptoms as given in the table below proves of considerable interest.

Proportion of Workers Complaining of Certain Specified Symptoms

(See Table D)

Sprayers of	Lacquers	Undercoats and Paints	Vitreous Enamel Castings	Sheet Meta
Headache	18	18	17	31
Dizziness	18	13	31	27
Constipation	15	8	14	23
Digestive Disturbance	13	18	20	34
Dyspnea	12	7	17	27
Loss of Weight	12	7	23	19
Poor Appetite	10	6	14	19
Gastric Pain	0	3	8	15

It will be noted that dizziness, constipation, digestive disturbances, dyspnea, loss of weight, poor appetite and gastric disturbances all increase among the men spraying on castings as compared with the group of undercoat sprayers and house painters, the sprayers on sheet metal generally show a still further increase of physical complaints on account of the large proportion of women involved.

D. Radiographic Studies

In the group of vitreous enamel sprayers we were of course chiefly interested in the problem of silicosis. X-ray pictures were therefore taken of thirty-three workers in eight different groups, and, eliminating one plate which could not be read, thirty-two pictures were submitted to Dr. H. L. Pancoast of the University of Pennsylvania for final judgment as to their significance.

The data relating to the workers whose chests were so examined in this survey are given in table O and the X-ray findings in this and the Pennsylvania survey are summarized in table P. Of 14 plates from Plant 19, the plant with admirable exhaust ventilation and very low dust count, not one showed any evidence of silicosis, although there were four cases of tuberculosis in this group. In Plants 28 and 29 (castings) with dust counts of between 1 and 5 million 5 plates were made, of which one showed silicosis probably first stage. In Plants 7 (castings) and Plants 7 and 28 (sheet metal) (average dust counts 18-30 million) 9 plates were examined of which one (from Plant 28) showed first, or more probably, second stage silicosis. Finally a single plate made in Plant 29 where the dust count averaged 445 million showed probable first stage silicosis. Thus altogether three positive cases of silicosis were obtained in a total of 32 examinations. In the Pennsylvania studies 7 out of 52 plates made from enamel sprayers or 13% showed positive silicosis.

It is of interest to note that our three positive silicosis cases had been employed for periods of 3.5 years, 5 years and 9 years, respectively. Of the 29 negative cases only 6 had been employed for over 3 years and as silicosis normally takes several years to develop to a recognizable stage it is worth noting that these examinations showed three out of nine workers examined who had been employed for over three years to be suffering from this disease.

E. General Summary of Vitreous Enamel Studies.

It appears from our study that the spraying of vitreous enamels involves a distinct silicosis hazard and—when the enamel contains lead as is usual in the spraying of casting—a lead hazard as well.

We find that the enamel sprayed on castings contains 4-26% of lead and 21-37% of silica, while the enamel sprayed on sheet metal shows little or no lead but a higher content (43-47%) of silica.

With practically no exhaust ventilation we may find an average of over 400 million dust particles per cubic foot of air breathed by the enamel sprayer; and with an exhaust of between 80 and 130 linear feet per minute we find 6 to 27 million. On the other hand, one plant with an average exhaust of 212 feet gave a very satisfactory reduction in fine dust particles.

The men spraying castings—a process involving both a lead and a silica hazard—show a marked excess of subjective symptoms as compared with the other groups of men studied, particularly in respect to dizziness, dyspnea and loss of weight while one positive case of silicosis was discovered. The group of 19 women and 7 men spraying on sheet metal showed a still more striking increase of subjective symptoms (27%, for example, complaining of dizziness and dyspnea) with two positive cases of silicosis.

TABLE A

Summary of Plant Findings

PLANT 1

Spraying done in three-story modern brick building, a city block in area. Clean and well ventilated; with plenum supply of warm air when needed.

23 men spraying on auto bodies; all examined.

Plant was using principally V. lacquer and undercoats. This lacquer on test showed over 9% benzol. They were also using some D. lacquer introduced recently. Dr. ______ the plant medical director, had spoken to me last May about the condition of their sprayers and thought that perhaps they should change the lacquer.

All exhaust ventilation was of the induced draft type with 30-inch ducts leading to the injectors some 20 ft. or more from the booths.

At the time of the survey visit the men were spraying from 25 to 77% of the time they were at the booth and a number of the men were spraying two sides of the cars in adjacent booths, both of which factors lessened the amount of benzol found in the air at test point. Their hazard at this rate of work was more than twice that indicated by the test and would be still greater when spraying for 85 to 95% of the time at the booth as was found to be the case at some other plants.

Undercoats used here are quick dryers and contain some benzol.

Air measurements taken at 10 booths ranged from 4 to 112 ft. per minute, and averaged 51.5 ft. with lacquer.

3 benzol tests were made with man spraying 77% of the time, averaged 823 p.p.m. benzol.

1 primer test for benzol was made with the man spraying 77% of the time, averaged 225 p.p.m. benzol.

5 lacquer tests for benzol were made with the man spraying 42-45% of the time, and averaged 432 p.p.m. benzol.

All booths in which benzol tests were made were staggered right and left booths on a spray line with top and one side only.

Air measurements at three single three-sided booths arranged side by side averaged 37, 43 and 90 ft. per minute. Benzol tests at these and also at a number of booths in plants 2 and 4 had to be discarded as they were made with red acid. This is explained in the chemical section of the report.

One canopy booth with no sides and exhaust from the top only gave velocities averaging 26.5 ft. per minute.

Benzol Tests

Booth 1-a	av. vel. 58 ft. (78)	benzol 965 p.p.m.	av. of 2 tests.	nearest window.
b		930	2	nearest window.
c		575	2	twin away from window.
Booth 2	112 ft. (75)	255	2	primer.
Booth 3-a	87 ft. (75)	590	2	nearest window.
b		160	2	twin away from window.
Booth 4-a	29 ft. (26)	940	2	
b		47.5	2	
Booth 5-a	43 ft. (33)	420	2	
b	4.3 (10)	no test		

Velocities are usually averages of tests at from 2 to 5 points and where this is the case the no. in brackets is the test nearest the sampling tube inlet.

4 of the 23 men tested at this plant gave w.b.c. counts under 5600.
18 of the 23 men tested at this plant gave polymorph. counts under 4500.
Rating of Plant by workers in survey, this is order of general excellence of 6 plants where benzol tests were made.
S—2.
P—1. clean; lacquer booths crowded at times.
H—1. moderate amount of fume outside of booths.
V—1. men clean. Good type.

Both P and H made benzol tests and air measurements in this plant.

This high percentage of low blood counts and of symptom complaints are due to the benzol content.

PLANT 2

Spraying in several old 5-story brick buildings with only moderately good ventilation. Plenum system in places.

41 lacquer sprayers, 4 of whom also sprayed undercoats were examined; also 14 undercoat sprayers; 51 in all. This included all but a few spot sprayers.

This plant was using M.V. lacquer (1½% benzol by test) according to requirements of their customers; V. & P. lacquer (probably high in benzol as judged by air studies); H. lacquer (no information); D. lacquer (under ½% benzol). Both direct and induced draft type of booth exhaust were in use.

At the time of the survey visit they were spraying 85 to 95% of the time spent at the booth, except for one 20% and one 30-40%. They were using both quick drying and heat drying undercoats, the former usually containing benzol.

Air measurements made at 9 booths ranged from 10 to 143 ft. per minute, averaging 45 ft. per minute.

3 benzol tests were made as follows:
Man spraying D. oxide coat, 80% of time spraying, velocity 42 ft. 480 p.p.m. av. of 2 tests.
Man spraying D. lacquer 89% of time spraying, velocity 82 ft. 486 p.p.m. av. of 4 tests.
Man spraying D. primer, 92% of time spraying, velocity 10 ft. 160 p.p.m. av. of 2 tests.

These tests were at direct draft line booths with top and one side exhaust. The other lacquer used probably contained more benzol than D.

4 air tests for lead were made, only one of which was positive.
D. sand surfacer 80% time spraying vel. 143 ft. (120).001 lead per L.
D. primer (15% lead) 30-40% time vel. 49 ft. (32) .0.
D. primer (15% lead) 30-40% time vel. 49 ft. (32) .0.
D. glaze (3% lead) 20% time vel. 61 ft. (95) .0.

8 out of 41 lacquer sprayers gave w.b.c. counts below 5600.
26 out of 41 lacquer sprayers gave polymorph. counts below 4500.
7 out of 9 undercoat sprayers tested gave lead in feces.
7 out of 14 undercoat sprayers had blue lines on gums.

Rating of Plant.
S—5.
P—4. fairly clean.
H—6. dirty and dark, much fume at all booths, worse at undercoat booths.
V—6. workers definitely inferior to those at other plants.

H made most of air tests at this plant. V did not go through the plants and could form judgment only from the men as they came up for examination.

PLANT 4

Spraying in old brick and concrete building with good natural and plenum ventilation. All exhaust ventilation of direct draft type. Over 50 sprayers.

17 lacquer sprayers examined.

22 undercoat sprayers.

Plant using D and R.M. lacquers and undercoats.

At time of visit men were spraying 80 to 95% of time at booth.

All benzol tests made here were with red acid and so were discarded and it was not found convenient to return for more tests.

Air measurements at 3 booths were 65, 64 and 31 ft. per minute, average 53 ft.

3 air tests for lead with one positive.

R.M. oxide 2nd coat (24% lead) spraying 90% time, velocity 64 ft. (36) .096 lead per L.

R.M. oxide 1st coat (15% lead) spraying 95% time, velocity 49 ft., .0 lead.

R.M. oxide 1st coat (15% lead) spraying 95% time, velocity 49 ft., .0 lead.

No sprayers with w.b.c. counts below 5600.

8 out of 17 lacquer sprayers with polymorph. counts below 4500.
9 out of 12 undercoat sprayers tested showed lead in feces.
1 out of 22 undercoat sprayers tested had blue line on gums.

Grade of Plant.
S—4.
P—not in this plant.
H—3, considerable fume at all booths, men and floors dirty.
V—4. undercoat painters were very dirty.

PLANT 5.

Modern, well lighted and ventilated 5-story brick and concrete building. Spraying on 3 floors. About 75 sprayers. Both direct and induced draft types of booth ventilation.

25 lacquer sprayers examined.
28 undercoat sprayers examined.
Plant was spraying D. lacquer, F. lacquer, J. & D. thinner.
At time of visit men were spraying 60 to 90% of time at booth.

Air measurements at 4 booths averaged 63 ft. per minute (101, 68, 46 and 38 ft.).

4 benzol tests were made, 2 at special deep canopy type booth of plant design, without any sides, 1 at a box booth, and 1 at a regular type line booth with top and side.
D. lacquer spraying 91% of time vel. 101 ft. 905 p.p.m. benzol (2 tests).
F. lacquer spraying vel. 38 ft. 803 p.p.m. benzol (3 tests).
R.M. lacquer spraying 76% of time vel. 68 ft. 2200 p.p.m. benzol.
R.M. primer spraying 60% of time vel. 46 ft. 230 p.p.m. benzol.

One air test for lead:
R.M. primer (11% lead) 60% time vel .46 ft. .490 lead per L.

1 lacquer sprayer out of 25 with w.b.c. count under 5600.
8 lacquer sprayers out of 25 with polymorph. count under 4500.
2 undercoat sprayers out of 4 tested with lead in feces.

Grade of plant.
S—3.
P—5. very crowded, careless workers.
H— not in this plant.
V—4. the men appeared dirty.
This plant was just getting under way after a strike.

PLANT 6.

Spraying in modern 8-story brick and concrete building, spraying on 5th to 8th floors. Well ventilated, with induced draft booth exhausts.

All booths of twin type with exhaust from roof and one side. No crowding.

Last year this plant reported that it had much trouble from eye irritation from lacquer, much lessened with change of thinner. This plant has no appreciable labor turnover among workers and the men seem well contented. They were the best type of men seen on the survey.

27 lacquer sprayers were examined.

12 undercoat sprayers were examined. This included most of the sprayers in the plant.

At the time of the survey visit the men were spraying from 42 to 66% of the time at booth.

The plant was using D. lacquers and undercoats.

Only 2 kata air measurements were made at this plant as the kata was in use at an enameling plant at the time.

D & R surf. spraying 66% time vel. 54 ft. 248 p.p.m. benzol (2 tests)
D surfacer spraying 52% time vel. 92 ft. 260 p.p.m. benzol (2 tests)
D primer spraying 42% time vel. good 170 p.p.m. benzol (2 tests)
D primer spraying 42% time vel. poor 475 p.p.m. benzol (2 tests)
D lacquer spraying variable 230 p.p.m. benzol
D lacquer spraying variable 211 p.p.m. benzol (3 tests)
D lacquer spraying both very slow 21 p.p.m. benzol
D lacquer spraying variable time vel. poor 3500 p.p.m. benzol
D lacquer spraying 61% 1253 p.p.m. benzol (2 tests)

D lacquer spraying 51% time vel. very poor 2350 p.p.m. benzol (4 tests)
10 tests for benzol average 872 p.p.m.
7 of these average 231 p.p.m.
3 of these average 2367 p.p.m.

6 air tests were made for lead.
2 tests D&R.M. surf. (9% lead) spray 66% time vel. 54 ft. .001 lead per L.
1 test D primer (12% lead) spray 42% time vel. poor .001 lead per L.
1 test D primer (12% lead) spray 42% time vel good .0 lead per L.
2 test D surfacer no lead spray 52% time vel. 92 ft. .0 lead per L.

No lacquer sprayers with w.b.c. counts under 5600.
6 out of 27 lacquer sprayers with polymorph. counts under 4500.
4 out of 9 undercoat sprayers tested showed lead in feces.
2 undercoat sprayers had blue line on gums.

Grade of plant.
S—1.
P—2. good type of men, no crowding.
H— not in this plant.
V—2. good working conditions but long hours, some days, and other days no work.

PLANT No. 17.

Old 5-story brick building, recently remodeled. Poor ventilation. This plant has a reputation for rapid labor turnover. At another plant of the same company the July turnover was over 100%. 50 full time sprayers.
Induced draft exhaust ventilation with 12-inch ducts leading to injectors 20 ft. or more away. 4 ducts to one stack.
20 ft. or more away. 4 ducts to one stack.
18 lacquer sprayers examined.

12 undercoat sprayers examined.
At the time of survey visit the men were spraying from 80 to 90% of time at booth, except in two booths where the time was 50% and 60%.
Using V. lacquer over 9% benzol.
Using M.V. lacquer 1.46%.
All booths staggered in pairs in line. A few special type canopy booths without side.

15 air measurements from minus 40 to 108 ft. per minute, average 46 ft.

24 tests for benzol.
V undercoats, 3 varieties, 90% time spray, vel. 43 ft. 8 p.p.m. benzol.
V undercoats, 3 varieties, 90% time spray, vel. 41 ft. 1310 p.p.m. benzol.
M.V. oil surfacer, 90% time spray, vel. 40 ft. away 350 p.p.m. benzol.
V lacquer, 60% time spray, vel. 102 ft. 1700 p.p.m. benzol (3 tests).
V lacquer, 50% time spray, vel. very poor, 2983 p.p.m. benzol (3 tests).
M.V. oxide, 80-90% time spray, vel. under 8, 240 p.p.m. benzol.
M.V. oxide, 80-90% time spray, vel. under 8, 320 p.p.m. benzol, by window.
M.V. primer, 90% time spray, vel. under 8, 0 p.p.m. benzol.
M.V. primer, 90% time spray, vel. under 8, 330 p.p.m. benzol, by window.
M.V. lacquer, 85% time spray, vel. 75 ft., 1850 p.p.m. benzol (2 tests).
M.V. lacquer, 85% time spray, vel. 79 ft., 1300 p.p.m. benzol (2 tests).
M.V. lacquer, 85% time spray, vel. 67 ft., 4500 p.p.m. benzol (2 tests).
M.V. lacquer, 90% time spray, vel. 108 ft., 1610 p.p.m. benzol (2 tests).
M.V. lacquer, 90% time spray, vel. 102 ft., 1300 p.p.m. benzol.
M.V. lacquer, 90% time spray, vel. 417 p.p.m. benzol (3 tests).
M.V. lacquer, 85% time spray, vel. 87 ft., 470 p.p.m. benzol (2 tests).
M.V. thinner, 80% time spray, vel. 19 ft., 1400 p.p.m. benzol (2 tests).
M.V. lacquer, 80% time spray, 4700 p.p.m. benzol.
M.V. lacquer, 80% time spray, 280 p.p.m. benzol. (2 tests)
12 undercoats tests average 286 p.p.m. 12 lacquers average 1876 p.p.m.

8 lead tests with velocities from minus 40 to 43 ft. per minute.

V undercoats (.01, .8, 6.3% lead) 90% time, 43 ft. vel., .0 lead
V undercoats (.01, .8, 6.3% lead) 90% time, 41 ft. vel., .007 lead per L.
M.V. surfacer (19.2% lead) 90% time, minus 40 ft., vel. .006 lead per L.
M.V. surfacer (19.2% lead) 90% time, 0 ft., vel. .0
M.V. oxide (8% lead) 80-90% time, under 8 ft., vel. .100 lead per L.
M.V. oxide (8% lead) 80-90% time, under 8 ft., vel. .0 lead.
M.V. primer (29% lead) 90% time, very slow, vel. .045 lead per L.
M.V. primer (29% lead) 90% time, very slow, vel. .045 lead per L.

1 out of 18 lacquer sprayers showed w.b.c. count below 5600.
7 out of 18 lacquer sprayers showed polymorph. count under 4500.
7 out of 10 undercoat sprayers examined had lead in feces.
2 out of 12 undercoat sprayers examined had blue line on gums.
Speed of work with resulting intensity of exposure varies much. Plant has recently reopened after remodeling.

Grading of plant:
S—6.
P—6. poor ventilation, much fume, dirty, crowded, poor types.
H—5. poor ventilation, crowded, much fume, dirty on O side, fair on P side.
V—6. men definitely inferior.

PLANT 18.

No benzol tests.
9 physical examinations of workers in line of 10 booths spraying lacquers and surfacers.
5 on side away from windows give velocities from 45 to 93 ft. f.m.p. av. 82.
5 on side near windows give velocities from 103 to 170 ft. f.p.m. av. 147.

Physical exam. numbers 288, 289, 292, 295, 296, 302, 304, 305, 307.
8 physical exams. of workers in group of 8 booths spraying undercoats.
1 booth av. 150 ft.
1 booth av. 95 ft.
1 booth av. 92 ft.
5 booths, exhaust too slow to measure.
Physical exam. numbers 290, 291, 293, 294, 297, 301, 303, 305, 307 (293 and 297 had previously sprayed lacquer).
3 men examined were not spraying in booths 298, 299, 300.

1 booth 60 ft. long for continuous line spraying of hoods:
5 tests on side away from windows av. 276.6 ft. per min.
5 tests on side near windows av. 223 ft. per min.
no physicals.
10 booths for spraying wheels range from 139 to 320 ft.
9 booths for spraying wheels range from 137 to 238 ft.
5 other booths range as follows: 87, 59, 58, 67, 43, 37 feet.
1 other booth too slow to measure.

Votes of Excellence.

S. Dr. Smyth
P. Dr. Pike
H. Smyth, Jr.
V. Mr. Van Meter.

TABLE B

Air Tests for Benzol

Plant No.	Booth No.	Test No.	P. P. M. Benzol Found	Mean Air Velocity Past Man's Nose	Visual Evidence of Good Ventilation	Gun Pressure	Relative Humidity	Dry Bulb Temp.	Gall ons Lacquer Used Per Day	Material Sprayed	% of Time Man is Spraying	Physical Exam. No.	Exposure is — Times as Great
1	1	138	1140	87	#	85	..	..	..	1	77	1	2
..	..	139	790	87	#	85	..	..	..	1	77	4	2
..	..	140	850	87	#	85	..	..	..	1	77	1	2
..	..	141	1010	87	#	85	..	..	..	1	77	4	2
..	..	142	390	87	#	85	..	..	..	1	77	1	2
..	..	143	640	87	#	85	..	..	..	1	77	4	2
..	2	144	210	84	0	85	..	..	..	2	77	2	2
..	..	145	300	84	0	85	..	..	..	2	77	2	2
..	..	146	..	84	0	85	..	..	..	2	77	2	2
..	3	148	0	87	.	80	..	..	..	3	45	5	2
..	..	149	860	87	.	80	..	..	..	3	45	5	2
..	..	150	320	87	.	80	..	..	..	3	45	5	2
..	..	151	320	87	.	80	..	..	..	3	45	5	2
..	4	152	1030	30	.	80	..	..	..	3	45	11	2
..	..	154	850	30	.	80	..	..	..	3	45	11	2
..	4a	153	51	30	.	80	..	..	..	3	45	11	2
..	..	155	44	30	.	80	..	..	..	3	45	11	2
..	5	156	180	40	.	85	..	..	..	3	42	3	2
..	..	157	660	40	.	85	..	..	..	3	42	3	2
2	6	130	830	42	.	80	..	..	40	4	80	..	..
..	..	131	130	42	.	80	..	..	40	4	80	..	..
..	7	132	0	82	.	80	..	..	40	5	89	39	..
..	..	133	74	82	.	80	..	..	40	5	89	28	..
..	..	134	1030	82	.	80	..	..	40	5	89	28	..
..	..	135	840	82	.	80	..	..	40	5	89	28	..
..	8	136	160	0	.	80	..	..	40	4	92	..	..
..	..	137	160	0	.	80	..	..	40	4	92	..	..
5	21	37	920	101	.	105	54	88	25	5	91	..	..
..	..	39	890	101	.	105	54	88	25	5	91	..	..
..	22	40	820	38	.	105	60	87	50	6	..	..	..
..	..	41	1080	38	.	105	60	87	50	6	..	..	..
..	..	42	510	38	.	105	60	87	50	6	..	..	..
..	23	44	2200	65	.	105	74	83	50	7	77	..	..
..	24	45	220	46	.	105	65	78	60	7	60	..	..
..	..	46	240	46	.	105	65	78	60	7	60	..	..
..	..	47	230	46	.	105	65	78	60	7	60	..	..
6	25	50	119	54	.	..	42	82	20	4, 7	66	..	..
..	..	51	380	54	.	..	42	82	20	4, 7	666	..	..
..	26	52	220	92	.	105	43	82	20	4	52	..	..
..	..	53	320	92	.	105	43	82	20	4	52	..	..
..	27	56	300	..	#	..	..	..	10	5	10	206	..
..	..	57	44	..	#	..	..	..	10	5	10	..	..
..	28	59	440	..	#	..	..	..	10	5	42	206	2
..	..	60	510	..	#	..	..	..	10	5	42	206	..
..	29	62	2400	..	.	100	..	..	20	5	61	198	..
..	..	64	107	..	.	100	..	..	20	5	61	198	..
..	30	65	3100	..	.	100	..	..	..	5	51	...	..
..	..	66	2500	..	.	100	..	..	..	5	51	...	..
..	..	67	1400	..	.	100	..	..	..	5	51	...	..
..	..	68	2400	..	.	100	..	..	..	5	51	...	..
..	31	69	21	..	.	100	..	..	..	5	51	205	2
..	34	70	3500	..	.	105	..	..	..	5	51	205	..
..	..	101	230	..	.	105	..	..	..	5	..	205	..
..	38	102	22	..	.	105	..	..	..	5	..	205	..
..	..	103	370	..	.	105	..	..	..	5	..	205	..
..	..	104	240	..	.	105	..	..	..	5	..	205	..
17	52	87	18	43	.	85	54	80	50	1, 2	90	257	..
..	53	88	1310	41	.	85	54	80	50	1, 2	90	256	..
..	54	89	0	..	.	85	33	89	28	8	90	260	..
..	55	90	350	40	.	95	33	89	28	8	85	261	..
..	56	91	240	10	.	85	33	89	100	8	85	258	..
..	..	92	320	10	.	85	33	89	100	8	85	259	..
..	57	93	0	..	.	95	30	100	55	..	90	..	..
..	..	94	330	..	.	95	30	100	55	..	90	..	..
..	58	105	2400	75	.	85	..	..	40	9	85	271	..
..	59	106	1300	..	.	85	..	..	40	9	85	271	..
..	60	107	1300	79	.	85	..	..	40	9	85	272	..
..	61	108	4500	67	.	85		..	40	9	85	269	..
..	62	109	2400	108	.	100	..	..	40	9	90	278	..
..	..	110	820	108	.	100	..	..	40	9	90	278	..
..	63	111	1300	102	.	105	..	..	40	9	90	280	..
..	..	111a	670	102	.	105	..	..	40	9	90	..	..
..	64	117a	0	..	.	105	..	..	40	9	90	270	..
..	65	123	590	..	.	105	..	..	40	9	90	277	..
..	66	112	1900	102	0	105	..	..	20	3	60	..	..
..	67	113	1300	..	0	105	..	..	20	3	60	..	..
..	66	112a	1900	102	0	105	..	..	20	3	60	..	..
..	68	114	1700	..	.	105	..	..	20	3	50	..	..
..	..	115	750	..	.	105	..	..	20	3	50	..	..
..	..	116	6500	..	.	105	..	..	20	3	50	..	..
..	69	117	1400	19	.	105	..	..	40	9	80	..	..
..	..	118	450	19	.	105	..	..	40	9	80	..	..
..	..	119	4700	19	.	105	..	..	40	9	80	..	..
..	..	118a	110	19	.	105	..	..	40	9	80	..	..
..	..	120	360	87	.	100	..	..	40	9	85	264	..
	..	120a	590	87	.	100	..	..	40	9	85	264	..

Table C 1—LACQUER SPRAYERS

Physical examination number	Industry number	Plant number	Age	Married or Single—	Number of children	White Colored—c	Materials sprayed	Years or months spraying (yrs. as whole numbers, months as decimals)	Air velocity in ft. per min. average of tests	Benzol in air in p.p.m. average of tests	Mil. r.b.c. per cu. mm. blood	W.B.C. per cu. mm. blood	Ratio of one w.b.c. to no. r.b.c.	Calculated polymorphonuclear count	% Polymorphonuclear count	Calculated lymphocyte count	% Lymphocyte count	% Large mononuclear count	% Eosinophile count	% Basophile count	Stipple cells per 100,000 r.b.c.	Basophilic aggregations (McCord)	Number of w.b.c. counted in hundreds	% Hemoglobin	Color index	Systolic blood pressure	Diastolic blood pressure	Pulse pressure
1	22	1	24	—		c	L	2	good	803	5.2	6800	770	3808	56	2482	36	5	.5	1.5			2	70	.66	110	61	49
2			42	#	0		L	.04	med.	210	5.3	6600	800	4158	63	1848	28	4	3	2			2	70	.66	130	92	38
3			31	#	1		L(Pr)	1	poor	420	4.2	10200	410	6579	64	2805	27	6	1	1			2	75	.88	130	85	45
4			22	—			L	.11	good	803	4.2	5700	750	3477	61	1938	34	3.5	1	.5			3	70	.81	125	84	41
5			22	#	0		L(P)	3	poor	375	4.6				61		32	4	1.5	1.5			2	75	.80	122	74	48
6			22	—			L	.04			4.2	6500	650	4160	64	1690	26	6.5	3	.5			2	75	.87	121	78	43
7			28	#	1		L	5			5.2	4600	1130	3082	67	1288	28	4.5	.5				2	85	.81	132	91	41
8			35	—			L	5			5.7	8650	660	6141	71	2162	25	3	.5	.5			2	85	.74	131	86	45
9			48	#	0		L(PV)	4			4.4	7500	590	4650	62	2550	34	3	.5				2	80	.89	141	94	47
10			23	#	0		L(V)	1.08			4.1	11500	360	5635	49	5520	48	2	1				4	75	.90	108	68	40
11			26	#	0		L	1.06		494	4.0	6450	630	3999	62	2064	32	5	.5	.5			2	85	1+	118	86	32
12			26	—			L(V)	1.09			4.9	5150	960	3090	60	1802	35	4	1				2	85	.85	118	82	36
13			27	—			L	.09			4.4	5950	730	3689	62	2023	34	2	2				2	85	.96	112	73	39
14			25	#	0		L	2.06			3.8	9250	410	6382	69	2127	23	5.5	2	.5			2	78	1	131	92	39
15			39	#	1		L	1			4.9	5150	950	3502	68	1493	29	1.5	1	.5			3	80	.80	161	78	83
16			26	#	0		L P	3			4.4	6250	710	4010	64	2000	32	3	1				2	76	.85	130	84	46
17			30	#	1		L (PV)	7			4.1	7600	540	4408	58	3116	41	3.5	.5				3	69	.84	130	78	52
18			30	—			L	.07			4.6	6850	670	3767	55	2808	41	2.5	1.5				2	75	.80	130	86	44
19			36	#	0		L	3			3.7	6100	620	3294	54	2440	40	4.5	1	.5			2	76	1	128	84	44
20			24	—			L	.04			4.5	6650	680	4256	64	1995	30	2	2.5	.5			2	72	.78	115	84	31
21			52	#	5		L	.08			3.6	6800	530	4148	61	2380	35	3.5	1	.5			3	68	.92	144	89	55
22			22	#	0		L	2			4.9	6650	740	4123	62	2194	33	2	2	1			4	68	.68	122	78	44
23			36	#	0		L	1			4.6	5200	890	2526	68	1456	28	1.5	1.5	1			2	80	.86			
24	2	2	24	#	1	c	L	4			4.6	6700	690	3886	58	2412	36	2	3.5	.5			2	75	.80	120	80	40
25			22	#	1	c	L	4			4.8	4900	980	2303	47	2352	48	4	1				3	72	.74	152	91	61
26			22	#	0	c	L	3			3.8	7000	540	4060	58	2520	36	3	3				2	72	.93	132	82	50
27			33	#	1	c	L	8			4.3	5950	730	1844	31	3570	60	5	4				3	70	.80	160	108	52
28			25	—		c	L	6	poor	646	4.8	5450	880	2452	45	2725	50	3	1	1			1	75	.77	142	91	51
29			33	#	1	c	L	3			4.3	6750	650	3577	53	2902	43	3.5	.5				3	75	.85	138	84	54
30			24	#	1	c	L	4			4.7				36		57	6	.5	.5			3	68	.71	118	78	40
31			25	#	0		L	1.06							49		45	4.5	1.5				2	82		122	84	38
32			25	#	0		L	2			4.1	8350	500	5177	62	2672	32	4.5	.5	1			2	72	.86	138	94	44
33			52	#	6		L	2			4.8	5500	870	3300	60	1925	35	3	1.5	.5			2	74	.76	130	88	42
34			21	#	1		L	2			4.3	6600	650	4092	62	2178	33	4	1				2	72	.83	122	78	44
35			21	—			L	.03			4.2	9000	470	6300	70	2340	26	3.5	.5				2	80	.94	140	88	52
36			26	—			L	4			4.0	6400	630	4160	65	2112	33	2					2	80	.99	138	94	44
37			30	#	0		L	3.06			4.4	10250	130	7687	75	2235	22	2	.5	.5			3	80	.90	118	74	44
38			32	#	5	c	L	4			3.9	9750	280	6922	71	2437	25	3		.5			2	60	.78	156	94	62
39			24	#	1	c	L V	4	poor	0	3.9	5600	690	3024	54	2240	40	4	1.5	.5			3	88	1+	119	78	41
40			22	#	2	c	L	3			4.9	4800	1020	1536	32	2880	60	6	1	1			3	70	.70	111	72	39
41			53	#	1		L (P)	4.06			4.7	4050	1160	2146	53	1620	40	6	1	1			3	78	.80	140	93	47
42			23	#	0	c	L	2.06			5.0	6350	790	4318	68	1714	27	4	.5	.5			2	73	.71	118	79	39
43			38	#	0		L	3			5.1	6900	740	4416	64	2001	23	6	.5	.5			5	75	.72	144	88	56
45			23	#	1	c	L Pr.	3			3.5	6850	510	4452	65	2192	32	2.5	.5				2	58	.81	150	96	54
48			27	—			L	.06	polisher		4.3	9200	470	5612	61	3404	37	1	1				2	72	.82	128	72	56
50			27	#	2	c	L U	3			4.3	8000	540	4800	60	2880	56	3	.5	.5			2	78	.89	122	76	46
52			32	#	1		L	1			4.6	7500	620	3075	41	3965	53	5	1				3	72	.77	154	98	56
53			22	—		c	L	.06	cleaner		4.3	6050	720	3327	55	2541	42	3					2	75	.85	138	96	42
54			21	—		c	L U	.07	cleaner		4.6	8800	520	3872	44	4488	51	4	.5	.5			3	75	.80	141	88	53
60			23	—			L	.10			5.0	8400	600	4788	57	3360	40	2	.5	.5			2	90	.88	162	84	78
61			21	—			L	.04			3.8	10450	360	6374	61	3553	34	4	.5	.5			2	80	1+	132	88	44
62			24	—			L	3			4.2	7650	550	4437	58	2907	38	2	1	1			3	85	1+	140	98	42
63			25	#	0		L	3			4.5	6200	730	4092	66	1860	30	2	2				2	75	.82	126	88	38
64			25	#	2		L	2.06			4.8	10200	470	6018	59	3774	37	2	.5	1.5			2	90	.92	150	98	52
65			40	#	0		L	.06			5.1	5800	870	3016	52	2668	46	1.5	.5				2	68	.66	132	84	48
66			19	—			L	.04			5.0	9850	510	6205	63	3152	32	2	3				2	87	.86	124	78	46
67			42	#	1		L Pr.	7			4.4	6400	690	3840	60	2368	37	2	1				2	70	.78	198	114	84
68			25	—			L	.02			3.6	10000	360	5600	56	4200	42	1	.5	.5			2	89	1.2	122	88	34
69			22	—			L	1			5.4	6900	780	3864	56	2898	42	1	1				2	85	.78	128	84	44
70			36	#	2		L	1			4.0	6500	610	3575	55	2600	40	3	2				2	70	.87	128	86	42
71			23	#	1		L	3			4.5	5350	840	3763	61	1979	37	1	1				2	85	.93	134	76	58
72			19	—			L	.06			3.0	5550	540	2830	51	2553	46	1.5	1	.5			2	70	1.1+	112	82	30
73			33	#	0		L	.07			4.0	6050	670	2904	48	2843	47	2.5	.5	2			2	85	1+	130	88	42
74			35	#	2		L	3			3.9	5800	680	4582	79	1102	19	2					2	70	.87	141	86	55
99	2	4	31	#	2		L	8			4.3	8400	510	5208	62	2856	34	3	1				2	75	.86	112	72	40
100			36	#	5		L	8			3.8	7300	530	3650	50	3139	43	3	1	3			3	75	.96	142	92	50
101			33	#	0		L	7			4.6	10600	430	4558	43	5406	51	4	.5	1.5			4	90	.96	110	70	40
102			32	#	3		L	2.06			4.5	6300	710	2961	47	2835	45	4	2	1			3	80	.88	128	78	50
103			27	#	0		L	3.06			4.2	7500	560	4725	63	2400	32	2.5	1	1.5			2	72	.85	128	82	46
104			34	#	1		L	2.06			4.9	7650	640	4819	63	2448	32	1	2.5	1			2	79	.79	142	86	56
105			32	#	1		L	7			4.5	7700	590	4774	62	2618	34	2	1	1			2	76	.83	108	64	44
106			24	—			L(V)	.05			4.3	12400	350	9424	76	2480	20	3	1				3	79	.90	112	68	44
107			26	#	1		L	5			4.7	8400	560	5628	67	2520	30	1	1	1			2	78	.82	148	82	66
108			20	—			L	2			3.9	9100	430	4414	54	3822	42	1.5	1.5	1			2	90	1+	130	66	64
109			21	#	0		L	3.06			4.3	8450	510	5408	64	2535	30	4	2				2	94	1+	128	58	70
110			23	#	3		L(Ru)	5.06			4.0	7600	530	4408	58	2888	38	3.5		.5			2	69	.84	142	90	52
111			23	—			L	2.06			4.4	6400	690	3968	62	2240	35	2		1			2	95	1+	128	88	40
112			25	#	0		L	4			4.0	8200	480	5166	63	2788	34	4		1			1	85	1+	124	70	48
113			24	#	1		L	4			4.1	6600	620	3564	59	2640	40	2	2				2	82	.99	130	92	38
114			27	#	0		L	.06			4.7	7200	650	4032	50	2952	41	2	.5	.5			3	93	.98	120	82	38
117			20	—			L	1.06			4.6	6400	720	3328	52	2560	40	5	2	1			2	87	.91	110	68	42
138	2	5	35	#	4		L(Gl.)	1.01			4.7	10500	450	6300	60	3885	37	2	1				2	80	.83	138	92	46
139			25	#	1		L	3			4.4	9350	470	3927	42	4862	52	5	1				3	80	.90	134	88	46
151			29	—			L	1.06			4.0	10450	380	6061	58	4075	39	1.5	1	.5			2			118	78	40
153			25	#	0		L	3			4.8	7200	670	4248	59	2664	37	2	1	1			2	70	.72	138	86	42
154			23	#	0		L	2			4.0	6300	640	3906	62	2142	34	3	.5	.5			4	75	.81	122	84	38
155			26	—			L	6			5.1	5550	220	3330	60	1942	35	3.5	1	.5			3	78	.59	132	88	44
156			50	#	3		L	2			4.6	7800	590	5538	71	1950	25	2.5	1	.5			3	80	.86	134	88	46
157			24	#	0		L	4			4.2	7250	580	4495	62	2392	33	3	1	1			2	75	.88	144	84	60
158			23	#	0		L	1			4.3	8150	520	4401	54	3586	44	2					3	88	1+	138	84	54
159			21	—			L(V)	1			4.8	7450	650	4544	61	2533	34	4	1				2	75	.77	140	94	46
160			25	#	1		L(U)	1			4.1	8600	470	4730	55	3612	42	2	.5	.5			2	85	1+	122	84	38
161			22	—			L	.08			4.2	12400	340	9424	76	2728	22	1.5	.5				3	73	.86	130	78	52
162			31	#	0		L	5			3.6	9300	390	5859	63	3255	35	2					3	65	.89	112	78	34
163			30	#	2		L	3			5.1	8600	600	3956	46	4300	50	2.5	1.5				3			128	78	50
164			20	—			L	4			4.6	9250	480	4625	50	4440	48	1.5		.5			3			118	72	46
165			24	#	1		L(Ru)	1			4.5	9550	490	4775	50	4488	47	2	.5	.5			3	72	.78	124	78	46
166			23	#	0		L	2			4.7	11700	400	7371	63	3744	32	4	1				2	70	.74	162	98	64
167			22	#	0		L	.04			4.6	7950	580	4929	62	3782	35	2.5	.5				3	80	.86	118	74	44
168			35	#	3		L(Ru)	.06			4.4	8450	520	4563	54	3633	43	2	.5	.5			4	70	.79	132	78	54
169			48	#	5		L (PV)	2			3.9	8750	450	5787	65	2800	32	1.5	1.5				2	70	.87	136	98	38
171			35	#	2		L	1			4.2	8300	510	4648	56	3403	41	1.5	1	.5			3	72	.83	138	96	42
172			28	#	3		L(Gr.)	.06			3.9	8500	460	5100	61	2975	35	2	1				3	63	.80	122	84	38
173			24	#	2		L(Gr.)	1			4.3	9550	450	6207	65	2674	28	4.5	1.5	1			2	70	.80	130	86	44
174			28	#	1		L	.04			4.4	6150	710	3874	63	2029	33	2.5	.5	1			2	75	.85	118	82	36
175			23	#	0		L (Gr.)	.03			4.2	9450	440	6142	65	2835	30	3	1	1			2	74	.88	124	78	46
191	2	6	42	#	0		L(P)	3			4.1	11150	370	7693	69	3010	27	2.5	1	.5			2	85	1+	146	92	54
192			24	—			L	2			4.9	10350	470	5899	57	3622	35	4	3	1			2	92	.93	142	78	64
193			31	#	2		L	3			4.1	9650	420	6658	69	2798	29	1	1				6	76	.92	122	76	46
194			24	#	1		L	2.08			5.0	8650	580	5103	59	3200	37	1.5	1.5	1			3	80	.79	120	74	46
195			34	#	5		L	4			4.9	9500	510	3895	41	5130	54	3	1	1			4	87	.88	124	78	46
196			25	—			L	2.06			4.7	8950	520	5280	59	3222	36	3	1.5	.5			2	80	.84	118	72	46
197			24	#	1		L(U)	.06			4.7	9450	500	5386	57	3595	38	2	2.5	.5			3	86	.90	128	78	50
198			39	#	3		L	.08	poor	1253	4.8	8050	600	5635	70	2093	26	2.5	1	.5			3	78	.80	156	92	64
199			52	#	3		L	6			4.6	7450	600	5215	70	1862	25	4.5	.5				2	82	.88	162	98	64
200			40	#	2		L(P)	6			4.5				67		27	5	1		25		2	82	.89	132	84	48
201			28	—			L	2			4.5	9300	490	6417	69	2418	26	3	2		33		2	88	.96	112	72	40
202			28	#	0		L	.06			4.8	10400	460	6656	64	3328	32	3	.5	.5	25		2	78	.80	138	88	50
203			20	#	0		L	1.03			4.9	8606	570	3956	46	4214	49	2.5	2	.5			3	90	.90	108	64	44
204			33	#	0		L	3.06			4.5	6450	700	4128	64	1935	30	3.5	2.5		50		2	84	.92	112	72	40
205			35	#	0		L	.01		230	4.3	10000	430	6200	62	3000	30	4	3	1			2	72	.82	124	82	42
206			25	#	0		L	.06	good	318	4.8	8200	590	4346	53	3362	41	4	1.5	.5	28		3	80	.81	136	72	64
207			33	#	2		L	3			5.0	8600	580	4902	57	3268	38	2	3				2	85	.84	114	68	46
208			31	#	3		L	3			4.5	10000	450	6900	69	2500	25	3	3		0		2	90	.98	118	74	44
209			22	—			L	2			5.0	7000	720	3850	55	2800	40	3.5	1.5		0		2	95	.93	132	68	64
210			20	—			L	.01			5.1	10400	490	6032	58	3744	36	4.5	1	.5	50		3	90	.87	114	62	52
211			24	#	1		L	.005			4.8	11900	400	5831	49	5355	45	3	2	1	0		3	82	.85	132	74	58
212			58	#	1		L	.07			4.4	9950	440	5870	59	3582	36	3.5	.5	1	25		2	89	1+	118	78	40
213			21	—			L	.10			5.0	9650	520	5983	62	3184	33	4	1		163		2	83	.81	128	68	60
214			30	#	0		L	.01			4.7	10050	460	6130	61	3316	33	3	2	1	0		2	75	.79	122	72	50
215			23	#	1		L	.06			5.1	9700	520	4171	43	4850	50	4	2	1	0		3	91	.89	128	82	46
216			22	—			L	1			4.5	7760	580	5115	66	2247	29	2	2	1	0		2	80	.88	118	78	40
217			36	#	1		L	1.01			4.6	10250	450	6150	60	3690	36	2	.5	1.5	0		2	80	.85	112	72	40
264	2	17	27	#	1	c	L	4	87	475	3.9	5350	740	3977	65	1605	30	3	2				2	58	.73			
265			30	#	3	c	L	2			4.3	10050	430	6532	65	3015	30	2	2	1			2	70	.80			
266			22	#	0	c	L	2			4.2	9200	460	4876	53	3772	41	3	2	1			2	70	.81	130	74	56
267			32	#	1	c	L(Pr.U)	.03			3.9	6850	570	3630	53	2740	40	3.5	2.5	1			2	78	.98	148	88	60
268			25	#	0	c	L(P)	1			4.5	8450	530	2619	31	5070	60	6	2	1			3	85	.94	128	81	47
269			34	#	1	c	L	4	67	4500	4.3	7750	550	4805	62	2635	34	2	1.5	.5			2	70	.81	148	88	60
270			23	—		c	L	3	102	0	4.1	7200	580	4320	60	2304	32	4	3.5	.5			2	75	.89	114	70	44
271			27	#	2	c	L	.06	75	1850	4.7	11250	410	7200	64	3150	28	4	3	1			2	82	.87	124	78	46
272			25	#	0	c	L	.06	79	1300	4.2	5800	720	3164	58	2208	38	2	2				2	72	.85	98	58	40
273			24	—		c	L	.02			4.8	6600	730	4620	70	1716	26	2	1	1			2	85	.87	131	92	39
274			21	—		c	L	1			4.4	7800	560	4524	58	2808	36	4	2				2	76	.86	114	68	46
275			37	#	2	c	L	4			4.2	6550	650	3471	53	2685	41	2.5	3	.5			4	80	.94	112	74	38
276			30	#	1	c	L	1			4.2	8400	500	4536	54	3360	40	3.5	2	.5			3	80	.93	124	82	42
277			28	#	1	c	L	1	102	590	4.3	9600	450	6336	66	2688	28	1.5	4.5				2	90	1+	112	76	36
278			28	#	2	c	L	3	108	1610	4.8	10600	450	3816	36	6148	58	3	3				2	75	.77	109	68	41
280			32	#	0	c	L	.06	102	1300	3.8	7350	520	4233	58	3419	37	3	1	1			2	65	.83	96	62	34
284	surv	vey	23	—			Letc.	1.01			4.9	5200	940	4036	68	1456	28	3	1				1	90	.91			
287	surv	vey	28	—			L	1			5.4	5750	900	3925	70	1667	29			1			1	84	.84			
288	2	18	39	#	1		L	.08			3.9	6200	630	2790	45	3100	50	3	1.5	.5			3	91	1.1			
291			35	#	1		L(V)	.07			5.2	5400	960	3834	71	1296	24	3	2				2	90	.86			
292			28	#	0		L	.10			4.9	8100	610	5427	67	2268	28	2	2.5	.5			2	82	.82			
295			31	#	2		L	1.06			4.8	5550	860	3441	62	1831	33	4	1				2	88	.91			
296			20	#	1		L	2			5.6	8700	640	6090	70	2088	24	3	1.5	1.5			2	95	.84			
298			37	#	1		L	2			4.8	7250	670	4867	67	2102	29	2	1.5	.5			2	85	.87	130	82	48
300			31	#	2		L(E)	2			4.5	8300	550	4565	55	3237	39	2.5	1.5	2			2	85	.92	129	72	57
302			23	#	0		L	.08			4.6	4800	970	2016	42	2400	50	3.5	3.5				3	83	.88	121	68	53
304			32	#	3		L	3			4.5	7050	640	4864	69	1903	27	2.5	1.5				2	73	.80	112	70	42
305			45	#	4		L	3			4.3	4800	900	2928	61	1728	36	2	1				2	78	.90	116	78	38
306			26	—			L	4			5.1	9850	520	6597	67	2959	30	2	1				2	75	.72	110	64	46
324	2	22	25	#	0		L	.10			4.8	6000	810	3360	56	2220	37	3	3	1		2+	2	90	.92	130	84	46
325			40	#	1		L	1.02			5.2	6800	770	3944	58	2584	39	2.5	.5	1		2+	2	83	.78	146	98	48

Physical examination number	Albumin	Sugar	Casts	Cylindroids	W.b.c. or pus cells in urine	R.b.c. in urine	Epithelial cells in urine	Oxalate crystals	Urate crystals	Loss of weight	Poor appetite	Digestive disturbances	Constipation	Headache	Dizziness on stooping or otherwise	Coryzas	Post-nasal irritation	Bleeding (N-nasal)	Dyspnea on exertion or otherwise	Other symptoms	Infections in last 5 yrs. before starting to spray	Infections since spraying	Previous related occupations	Other remarks	Use of alcohol (1—occasional, 2—moderate, 3—heavy)	Use of tobacco (1—irregular, 2—moderate, 3—heavy)	Rash from cleaner, etc.
1					#	#						#					#		#	chilly, cough			polisher 3 yrs.	throat irritation	2	2	
2					#					#	#				#					weakness						1	
3					#	#										#		N	#	eyes blur, finger numb			putty 2 yrs.	irregular heart	1	1	
4					#	#								#				N		cough	typhoid		cleaner 4 yrs.	polyuria, nocturia			
5					#					#		#	#				#					influenza, measles	body mover 1 yr.		2	2	
6					#			#			#	#	#				#			eyes burn			body mover 1/6 yr.	polyuria	2	2	naphtha rash
7		no sample															#			eyes burn				polyuria	1	2	
8					#G			#								#	#						assembler 10 yrs.		1	1	thinner rash
9					#	#							#							eyes burn, finger numb						2	
10					#															finger numb		tonsillitis					
11											#	#		#						winter cough after conjunctivitis	pneumonia	tonsillitis	varnisher 5 yrs.		2	3	
12										#	#		#	#	#				#				varnisher 1½ yrs.	in fume 21 months	2	2	
13										#	#				#		#						putty, paint 9/12 yr.			2	thinner rash
14					#															chest pains			varnisher 4 yrs.	polyuria, nocturia, burning			
15					#							#								mitral stenosis			varnish, glaze 5½ yrs.	irregular heart	3	2	
16					#																			polyuria and burn with paint	1	3	
17					#					#		#		#	#		#	N								1	
18					#		#							#			#						varnish rubber 5 yrs.		2	2	thinner rash
19																							painter 7 yrs.	dopy with poor fan action			
20														#						eye irrit., dry cough			varnisher 2½ yrs.	polyuria	1	2	
21																	#			eye irrit., chilly			varnisher 5 yrs.	polyuria	1	1	
22											#	#		#	#				#						1	3	
23																				eye irrit.	influenza				2	1	
24					#G		#				#						#			eye irrit.					2	2	
25					G															eye irrit.						1	
26					#G						#		#		#		#						truck 3 yrs.				
27		no sample																									
28	Tr.				#																		truck		3	2	
29					#																malaria				1	2	
30					#	#																bronchitis				1	
31					#																	pneumonia					
32					#	#	#			#	#	#	#			#	#			gags on starting		urinary tract inf.	varnish rubber 3 yrs.	polyuria, nocturia, burning	1	1	
33					#		#						#				#									1	
34																	#	N	#	cough at first		tonsillitis	varnish 8 yrs.		3	2	
35																						pneumonia	painter 2 yrs.		3	2	
36																	#		#	eye irrit.					2	3	
37																	#	N	#			tonsillitis	varnisher 8 yrs.		3	2	
38																			#						3	2	
39													#	#											2	2	
40					#										#										3		
41										#					#		#			pharyngitis, fingers numb		winter cough aft. hay f.		chest oppression, nocturia, neuritis			
42					#G					#		#	#	#	#		#		#	eye pain		tonsillitis		oppression		2	thinner rash
43					#G									#	#												
45																				eye irrit.			truck	polyuria, nocturia	2	2	
48																				eye irrit., heart irreg.						1	
50																				conjunctiva pale				intestinal worms, no lead in feces		1	
52					#		#																	nocturia frequent, .3 lead in feces			
53					#																		truck 8/12 yr.		1	1	
54																							truck 4/12 yr.				
60																				eye irrit.			polisher 3 yrs.	spot sprayer			
61																							sander 2/12 yr.	spot sprayer	2	1	
62																				eye irrit.			painter 3 yrs.	spot sprayer	2	2	
63					#															eye irrit.			varnisher 3 yrs.	prefers brush			
64	Tr.				#G										#					eye irrit.	measles	influenza	rubbing 4 yrs.		3	3	
65																				eye irrit.	influenza		painter 20 yrs.	prefers brush	2		
66	Tr.				#		#			#			#									bronchitis			1	1	
67					#G								#		#				#	eye irrit., mitral systolic		carbuncles last winter	painter 7 yrs.	prefers brush, nocturia, lead colic 12 yrs. ago			
68					#																				2	2	
69																						typhoid, diphtheria	polisher 2 yrs.		2	3	
70									#						#		#			eye irrit., throat sore			painter 17 yrs.	prefers brush, tires easily, 2 attacks of lead colic			
71					#													NI							2	3	
72					#				#	#	#	#	#		#								sander 1/12 yr.	polyuria, nocturia	2	2	
73																		NI	#						1		
74																				eye irrit., mitral murmur				jejunal ulcer, nervous, lack of concentration	3	3	
99										#										languid, nervous					1	1	
100						#																					
101																				eye irrit.		influenza			2	2	
102	Tr.																			lips pale				backache	2		
103					#G							#								eye irrit.		diphtheria	color varnisher 4 yrs.	prefers spray	3	3	
104																								coughs at first	2	3	
105																									3	2	
106																							dipper 3 yrs.				
107																							sprayed varnish 2 yrs.		2	1	
108																											
109	Tr.				#						#	#								dry throat					2	3	
110																				weakness				polyuria, nocturia, leaded, by Ru.			
111																									2		
112																									2		
113																				eye irrit.				polyuria		2	
114											#									lacks tone				polyuria, burning	2	2	thinner rash
117																#				rhinitis, diarrhea			dipper 1 yr.		1	3	
138																	#		#	eye irrit., oppression			sander, glaze 10/12 yr.	leaded while sanding	1	2	
139																							taker off 10/12 yr.	spot sprayer	2	1	
151		no sample																							1	1	
153																				muscular weakness			inspector 6/12 yr.		1	1	
154							#													eye irrit. at first			truck 3 yrs.		1	1	
155	Tr.																								1	1	
156																							finisher 6/12 yr.	inspector	2		
157																									1		
158																											
159		no sample																		eye irrit.			truck 2/12 yr.		2	2	
160																							varnish spray 2 yrs., lead spray 2 yrs.	leaded by spray 2 yrs. ago	1		
161																						tonsillitis	truck 6/12 yr., sander 3/12 yr.		1	2	
162											#	#	#	#	#					eye irrit., tingling, weakness			sander 1 6/12 yrs., leaded twice	polyuria, nocturia, burning; mitral murmur	2	3	
163																				eye irrit., chilly			sander 6/12 yr.		2	1	
164					#															eye irrit., nervous				cough, expectoration, weakness	1	2	
165					#					#	#	#								eye irrit., forgetful, weak		tonsillitis	ruff stuff 2 yrs.	cramps with ruff stuff	1	3	
166					G																		truck 1 yr.		2	2	
167					#															eye irrit.			clean up 1½ yrs.				
168																				eye irrit.			painter 2 yrs.		2	1	
169																				eye irrit., tingling			ruff stuff 5½ yrs., spray paint & varnish 17 yrs.		2	3	
171															#					legs weak		small-pox	sand inspector ½ yr.	nocturia	2	1	
172		no sample																					spray ground 4/12 yr.	painter burning urine leaded in sanding	1	3	
173	Tr.																			conjunctivitis	tonsillitis		spray ground ½ yr.		1	3	
174																							inspector			2	
175																							spray ground 1 yr.			1	
191		#			#																	tonsillitis	varnisher, spray lead 1 yr.				
192																									1	2	
193																											
194																							truck 1 yr.		1	1	
195																									3	1	
196																				eye irrit.		syphilis, chancroid			1		
197		no sample																		erythmia			lead undercoat spray 3½ yrs.		2		
198																						erysipelas	painter 22 yrs.		2	3	
199																				gall stones		tonsillitis			2	2	
200																							spray paint, etc., 6 yrs.	nocturia	3	3	
201																				eye irrit.			painter 14 yrs.		2	2	
202																							paint 1 yr., rubber 5 yrs.		2	3	
203																							color varnish 2 yrs.		2	2	
204																									1	2	
205																											
206																							sander 5/12 yr.	.01 mg. lead per L. air polyuria .005 lead per L.			
207	Tr.																			eye irrit.			flow coat ½ yr.		1	1	
208																				eye irrit.			painter 10 yrs.		1	2	
209																				eye irrit., erythmia			truck 3 yrs.				
210																				eye irrit.			rubbing 3 yrs.		2	2	
211					G															occasional dropped heart beat							
212																							painter 32 yrs.		3	2	
213																				eye irrit				spot sprayer	1	3	
214																							sander 2 wks.	polyuria			
215																				tingling		tonsillitis	color varnish 2 yrs.	core maker			
216																		N				tonsillitis	varnisher 4 yrs.	spot sprayer	3	1	
217		no sample																					paint 7 yrs.	5 mo. intermission recently, spot sprayer		2	
264																		N		hand tingles			truck	polyuria, nocturia	1	1	
265																							truck 2 yrs.		1	1	
266					G															eye irrit.			sprayed lead & primer 30/12 yr.			2	
267					G																						
268										#	#	#	#	#	#			N		eye irrit., hands tingle			sprayed paint 4 yrs.	muscular weakness	2	2	
269																									2	2	
270																										1	
271																							wet sanding 1 yr.			2	
272					G																		truck 2 yrs.			3	
273	Tr.				#G																		truck 1 yr.		1	1	
274					#																						
275																				knee reflex absent	influenza		truck	leaded from lacquer, spot sprayer, blue line on gums			
276		Tr.																					truck ½ yr.	spot sprayer	1	2	
277																									1	1	
278	Tr.																						truck 2/12 yr.		1	2	
280					G																pneumonia		truck ½ yr.		1	1	
284		no sample																									
287		no sample																									
288		no sample															#	N		eye irrit.			auto painter 7 yrs.			1	
291		no sample																		fingers numb			varnisher & painter 4 yrs.				
292		no sample																		burning throat	pneumonia		color varnish 8 yrs.	sprayed varnish 17 mo.	1	2	
295		no sample																					truck 2 yrs.			2	
296		no sample																							1	3	
298		no sample								#															2	1	
300		no sample								#													varnisher 6 yrs.	polyuria with varnish	2	2	
302		no sample																					sprayed enamel 10 yrs.	spot sprayer	2	1	
304		no sample																					truck 7/12 yr.		1	2	
305		no sample																N		mitral murmur				renal gravel	2	1	
306		no sample			G										#		#	N					flow paint & brush		2	1	
324		no sample																									
325																									3	3	

Table C 2—UNDERCOAT AND PAINT SPRAYERS

Physical examination number	Industry number	Plant number	Age	Married # Single —	Number of children	White Colored—c	Materials sprayed	Years or months of spraying (years as whole numbers; months as decimals)	Air velocity in ft. per min.	Mg. lead per grm. feces	Mg. lead per liter air	Benzol in air in p.p.m.	Mil. r.b.c. per cu. mm. blood	W.B.C. per cu. mm. blood	Ratio; one w.b.c. to no. r.b.c.	Calculated polymorphonuclear count	% Polymorphonuclear count	Calculated lymphocyte count	% Lymphocyte count	% Large mononuclear count	% Eosinophile count	% Basophile count	Stipple cells per 100,000 r.b.c.	Basophilic aggregations (McCord)	Number of white cells counted in hundreds	% Hemoglobin	Color index	Systolic blood pressure	Diastolic blood pressure	Pulse pressure
3	2	1	31	#	1		Pr. L	1					4.2	10200	410	6579	64	2805	27	6	1	1			2	75	.87	130	85	45
16			26	#	0		P L	3					4.4	6250	710	4000	64	2000	32	3	1				2	76	.85	130	84	46
44		2	23	#	1		Pr.	1.03		.2			4.6	8250	550	4042	49	3960	48	2.5	.5			3+	3	70	.76	126	76	50
45			23	#	1	c	Pr. L	3		.5			3.5	6850	510	4452	65	2192	32	2.5	.5			2+	2	58	.81	150	96	54
46			39	—			U	4	61		.0		4.4	8850	500	3363	38	5221	59	2		1		6+	3	75	.84	138	78	60
47			21	—		c	U	.07		.5			3.2	7200	440	3960	55	2952	41	3.5	.5			2+	2	70	1+	138	88	50
49			21	#	0	c	U	.11	140		.001		4.4	10100	430	4848	48	4545	45	5	1.5	.5		4+	3	78	.88	96	60.	36
50			27	#	2	c	U L	3	49	0	.0		4.3	8000	540	4800	60	2880	36	3	.5	.5		2+	2	78	.88	122	76	46
51			40	#	1		U	1		.8			4.4	6800	650	3060	45	3434	50	4	.5			0	3	70	.79	120	78	42
54			21	—		c	U L	.07					4.6	8800	520	3872	44	4488	51	4	.5	.5		0	3	75	.80	141	88	53
55			33	#	4		U	1		.4			4.8	6400	760	4544	71	1600	25	3	1			10+	2	58	.59			
56			22	—			U	.06		37			4.2	6950	610	4617	65	2085	30	3.5	.5	1		10+	2	50	.58	154	68	86
57			22	—			U	1					3.6	7100	500	4615	65	2130	30	5				+	2	60	.83	152	90	62
58			29	—			U	3					5.1	6900	730	4209	61	2415	35	3.5	.5			2+	2	85	.83	138	94	44
59			22	#	0		U	.06					3.9	12100	320	7381	61	3114	34	4.5	.5			10+	2	70	.88	128	74	54
67			42	#	1		Pr. L	7					4.4	6400	690	3840	60	2358	37	2	1			0	2	70	.78	198	114	84
75	2	4	32	#	2		Gl.	2.02		0			3.6	9800	370	6076	62	3528	36	2					2	75	1+	130	76	54
76			22	—			U	.09		16			4.8	9600	500	6144	64	3168	33	2.5	.5			6+	2	80	.83			
77			31	#	1		Gl.	4		2.1			3.2	10200	310	6018	59	3672	36	5					2	75	1+	130	74	56
78			26	#	1		Gl.	4		.4			4.8	8550	570	5215	61	3092	35	3.5		.5		4+	2	85	.87	128	76	52
79			27	—			U	.04		2.5			4.1	8400	480	5292	63	2772	33	3.5		.5			2	74	.90	128	76	52
80			45	#	2		U	3		.6			4.7	7600	620	3268	43	4028	53	4					3	85	.90	128	82	46
81			23	#	0		Pr.	2		0			4.7	6400	740	3392	53	1668	43	4				+	2	75	.78	128	78	50
82			21	—			Pr.	1.06		2.9			5.0	7450	670	3874	52	3129	42	5.5	.5				3	90	.88	120	72	48
83			24	#	0		U	4		1.9			4.8	8200	590	3034	37	4428	54	5	2.5	1.5			2	75	.77	106	72	34
84			24	—			U	2.06		1.8			4.2	5600	750	2352	42	2912	52	4.5	1	.5			3	82	.97	148	88	60
85			40	#	3		Pr. Sl.	12		0			2.8	7650	370	4513	59	2907	38	2	1				2	60	+1	142	74	68
86			35	—			U	7	56	.2	.048		3.9	11400	340	5700	50	5130	45	4	1				3	76	.96	134	88	46
87	4	3	22	#	1		P	6					3.8	7800	490	4524	58	2964	38	3.5	.5				2	75	.98	142	96	46
88			30	—			P	6					4.4	8650	500	5642	68	2508	29	1.5	1	.5			2	90	1+	134	86	48
89			30	#	0		P	8					4.0	10500	380	5040	48	4935	47	4.5	.5				3	75	.92	128	72	56
90			23	—			P	3					3.9	6800	570	3400	50	3128	46	4					3	70	.91	112	74	38
91	2	4	41	#	2		Ru. F	1.06					3.2	6550	490	4388	67	1834	28	3.5	1	.5			2	68	1-	130	80	50
92			28	—			Ru.	1					4.1	7800	520	3822	49	3254	43	6.5	1	1.5			2	80	.96	148	78	70
93			56	#	4		Ru.	6					4.4	13100	330	8908	68	3406	26	4.5	1	.5			2	72	.80	124	86	38
94			37	#	1		Ru.	.08					4.6	11600	400	7308	63	3828	33	3.5		.5		+	2	76	.81	128	70	58
95			30	—			Ru.	1					4.4	7500	580	4725	63	2475	33	2	1	1		6+	2	60	.68	112	76	36
96			27	#	0		Ru.	.03					4.2	12000	350	7440	62	3960	33	4		1		+	2	82	.97	138	86	52
97			43	#	0		Ru.	.04					3.9	9450	420	6042	65	2740	29	4	2				2	80	1	110	72	38
98			23	—			Ru.	.03					3.9	8250	480	4867	58	2970	36	3	1.5	.5			2	70	.85	128	78	50
115			21	#	0		Gr.	1					5.0	11550	430	7392	64	3811	33	3					2	85	.83	118	72	46
116			27	—			Gr.	1.06					4.3	8250	520	5775	70	2145	26	3.5		.5			2	82	.95	118	74	44
118	4	3	40	#	3		P	1.06					3.8	5450	700	3651	67	1635	30	2	1				2	73	.95	118	74	44
119			23	—			P	3					4.3	6300	680	4032	64	1827	29	4	1	2		2+	2	58	.66	121	78	43
120			23	—			P	2.06					3.6	8200	440	4756	58	3034	37	4		1			3	73	1	110	70	30
121			22	—			P	.01					4.6	6200	740	4092	66	1798	29	4	1				2			110	72	38
122			21	#	0		P	.01					4.8	10750	450	6940	64	3117	29	5	1	1			2	73	.74	128	78	50
123			29	#	0		P	1.06					4.0	6200	650	3596	58	2232	36	3	3				2	57	.69	118	78	40
124	2	5	34	#	0		Sl.	2.09		1			4.4	4950	900	2475	50	2128	43	5.5	1	.5			3	72	.80	132	84	48
125			20	—			Pr.	2.06					4.8	6300	760	2709	43	3087	49	5	2.5	.5			4	72	.74	124	82	42
126			47	#	6		Sl.	.04		0			4.6	8200	560	3854	47	3772	46	4	2	1			3	80	.86	182	110	72
127			28	—			Gl.Ox. Ru.	5					4.6	8050	570	4266	53	3461	43	3	1				3	80	.86	132	78	54
128			19	—			Sl.	.03					5.1	9800	520	6272	64	3136	32	3	.5	.5			2	70	.53	138	84	54
129			20	—			Gl.	.03					5.2	7300	700	4745	65	2336	32	2	1				4	74	.52	142	82	60
130			45	#	4		Sl.	.08					4.3	8900	480	5162	58	3293	37	4		1			2	72	.82	122	78	44
131			21	—			Gl.	.02					4.4	8400	520	5208	62	2856	34	3	.5	.5		+	2	74	.83	138	88	50
132			25	—			Gl.	1.06					4.4	9100	480	5096	56	3731	41	2.5	.5				2	75	.84	152	94	58
133			24	—			Gl.	.06					4.6	9250	500	5097	55	3885	42	2.5	.5				2	75	.80			
134			38	#	2		F	7		20			3.7	7350	510	5365	73	1690	23	2.5	1	.5		4+	2	59	.78			
135			18	—			Ox.	.05		0			4.5	9450	480	6237	66	2740	29	3	1	1			2	74	.80	148	96	52
136			30	#	1		Gl.	.06					4.3	8850	480	4425	50	4071	46	3	.5	.5			4	78	.90	124	82	42
137			26	—			Ru.	3					4.1	6100	670	2440	40	3477	57	2		1			4	78	.94	118	70	48
138			35	#	4		Gl.L&	1.01					4.7	10500	450	6300	60	3885	37	2	1			2	2	80	.83	138	92	46
140			23	#	1		Ru.	5					4.0	8400	480	4704	56	3192	38	3	2	1			3	75	.91	128	84	44
141			26	—			Gl.	.02					3.7	8350	440	5845	70	204	24	5	1				2	66	.88	142	86	56
142			29	—			Ru.	3					3.4	8750	380	4637	53	3587	41	4	1	1			3	65	.95	128	82	46
143			23	—			Ox.	1.10					3.4	10600	320	3710	35	6254	59	5.5	.5				4	75	1+	128	86	42
144			23	—			Ox.	1.04					4.6	9700	470	5820	60	3395	35	3.5	1	.5			2	80	.85	142	88	54
145			35	—			Ru.	6					5.0	8950	550	6265	70	2148	24	4	1	1			2	80	.78	134	78	46
146			32	#	2		All	4					4.5	7950	560	5485	69	2146	27	2	1.5	.5			2	80	.88	134	88	46
147			21	—			Ox.	1.03					4.4	10150	440	7206	71	2537	25	3.5	5				2	80	.89	152	92	60
148			42	#	9		Ru.	2					3.7	6600	560	4422	67	1980	30	2		1			2			132	86	46
149			29	—			Ox.	.05					4.3	7650	560	5661	74	1836	24	1.5		.5			2			152	88	64
150			18	—			Ox.	.06					4.2	9850	430	6107	62	3349	34	3.5	.5				2			144	96	48
152			28	#	1		Pr.	3					4.6	9750	470	5655	58	3607	37	4	1				2			120	76	44
170			20	—			Gr.	.08					4.6	11800	390	7198	61	4130	35	3	1				2	75	.80	142	88	54
176	4	3	28	#	0		P	3					4.2	6655	630	3857	58	2460	37	3.5	1.5				2	93	1.1	118	92	26
177			24	—			P	3.06					4.4	6050	730	3690	61	2178	36	3				3+	2	88	.99	128	88	40
178			42	#	0		P	.06					4.3	10800	390	6480	60	3780	35	2	2	1			2	80	.93	122	84	38
179	2	6	28	#	0		Pr.(L)	.03		4.4			4.5	5700	800	3920	60	2052	36	3	1			10+	2	70	.76	116	62	54
180			26	#	0		Pr.(L)	.02		23			4.8	8200	590	3936	48	3444	42	5	3	2		3+	3	75	.76	118	68	50
181			23	—			U(P)	3					4.9	7050	690	4441	63	2397	34	2.5	.5				3	85	.86	128	72	56
182			26	#	0		U(P)	2		0			4.5	10650	420	5857	55	4366	41	3	.5	.5		3+	3	80	.87	120	62	58
183			33	#	2		U(P)	2		0			4.5	7950	570	4929	62	2703	34	2	1	1		3+	2	78	.85	116	78	38
184			35	#	0		U(Ox.)	7		.5			4.4	8050	550	4669	58	2978	37	2	2	1			2	75	.84	138	82	56
185			33	—			U	.06		0			4.8	7650	630	3825	50	3289	43	4	3				3	79	.81	130	86	44
186			30	#	1		U(pr.)	4		0			4.6	8100	570	5184	64	3673	33	2	.5	.5		10+	3	78	.83	150	98	52
187			28	#	1		U Pr.	6		0			4.5	9450	480	4441	47	4630	49	1.5	2	.5			4	80	.88	110	60	50
188			27	#	5		U Gr.	6		.2			5.1	11100	460	7326	66	3219	29	3	2				2	78	.76	156	102	54
189			34	#	0		Sl.	.09					4.4	7300	600	2701	37	4234	58	3.5	1	.5			4	67	.75	110	74	36
190			29	#	1		Sl.	1.02					5.0	11800	420	7198	61	4130	35	2.5	.5	1		.	2	90	.88	132	74	58
248	4	11	21	—			P	4					4.3	13450	320	7801	58	5111	38	3	1		57	10+	2	85	.98	134	78	56
249			38	#	2		P	2					4.5	9300	490	5115	55	3534	38	4.5	2	.5	57	8+	2	97	1+	132	84	48
250			29	#	3		P	.01	300	58	.001		4.5				54		40	3	3			4+	2	80	.87	124	84	40
251			25	—			P	2		1.2			5.0	6000	830	2880	48	2820	47	2	2	1		4+	2	94	.93	128	78	50
252			23	—			P	5					4.8	5850	830	3159	54	2281	39	4	2.5	.5			2	85	.87	132	84	48
253	4	12	25	—			P	2.06	0		.0		5.0	8500	580	5695	67	2635	31	2					2	90	.89	128	88	40
254			21	—			P	3	0		.0		4.4	4200	1040	2688	64	1344	32	2	2				2	83	.94	128	80	48
255			21	—			P	2.06			.0		5.0	7150	700	4576	64	2216	31	3	1.5	.5		3+	2	80	.79	116	78	38
256	2	17	21	#	2	c	Pr.Gl.U	3	41	0	.007	1310	4.9	9800	500	5978	61	3626	37	1.5	.5				2	82	.83	116	68	48
257			24	#	1	c	Pr.	4	43	35	.0	18	4.4	8800	500	5016	57	2944	38	3	1	1		+	2	79	.89	146	98	48
258			28	#	2	c	Pr.	1.06	9	90	.0	240	4.5	9300	490	5301	57	3441	37	.5	4.5	1			2	80	.87	122	72	50
259			28	#	0	c	Pr.	.10	9	0	.1	320	4.5	7850	570	4553	58	2904	37	2	2	1			2	67	.73	116	70	46
260			26	#	0	c	U	.08			.0	0	4.7	10100	460	6363	63	3333	33	1.5	2	.5			2	75	.79	129	70	59
261			23	—		c	Gl.(L)	.01-	40	67	.6	350	4.6	9100	510	6097	67	2093	23	4	5	1		+	2	80	.85	124	72	52
262			19	—		c	U	.03		0			4.2	11550	360	8547	74	2425	21	2	2	1			3	68	.80	118	72	46
263			21	—		c	U	.01		77			4.4	7950	550	5316	68	2146	27	3	1.5	.5			2	60	.68	128	74	54
279			29	#	0	c	Sl.	.08					4.2	9400	440	4418	47	4230	45	4.5	3	.5			3	75	.88	116	72	44
281			30	#	1	c	Pr. U	3					4.4	8300	630	5312	64	2407	29	4	1.5	1.5			2	82	.92	98	62	36
282			23	#	0	c	Pr.	.06		5			4.7	7950	610	4213	53	3418	43	2.5	1.5				2	85	.88	141	86	55
283			25	#	1	c	U	.06		37			5.1	7300	700	4234	58	2404	33	8	1				2	82	.79	139	88	51
285	4	11	22	—			P	1					5.1	7950	650	5088	64	2146	27	7	1	1			1	90	.86	116	68	48
286			24	#	0		P	2.6					6.2				36		59					3+	3	90	.72	124	68	56
289	2	18	41	—			U	10		12			4.5	6000	750	3960	66	1740	29	4	1			10+	2	90	1	127	88	39
290			43	#	1		U	.09		45			4.5	4750	960	2232	47	2375	50	2	1				2	80	.87			
293			29	#	2		Ru.(L)	7					3.6	6800	540	3944	58	2584	38		3	1		10+	2	86	1.1			
294			33	—			Ru.	2		16			4.0	5800	690	3886	67	1682	29		1				2	85	1+			
297			22	#	1		Ru. (LS)	2.06					4.3	7100	610	4473	63	2272	32	2	2	2		10+	2	86	.97			
299			29	#	0		U	2					4.8	7900	610	4740	60	2923	37	1.5	1.5				2	85	.87	127	84	43
301			30	#	0		Pr.	5					5.2	8450	610	5408	64	2788	33	2	1			2+	2	85	.81	127	70	57
303			25	—			Pr.	2					4.6	7650	610	4590	60	2340	36	3.5	.5			10+	2	82	.87	122	68	54
307			35	#	1		Pr.	.04					5.1	6800	750	3808	56	2652	39	3.5	1	5		6+	2	85	.82	120	78	42
322	4	20	32	#	1		P	3.06	all fr ber pain	om t on a ters	his n re ho	num use	5.0	7650	650	4743	62	2677	35	2	1			2+		80	.79	116	70	46
323	23	21	22	—			P	1.04					5.0	9500	530	3886	58	2546	38	2	2			+		87	.86	124	88	36
326	4	22	23	—			P	.02					5.8	8300	700	5395	65	2573	31	2.5	1.5	1				89	.75	132	82	50
327			28	#	0		P(L)	.10					5.0	8950	560	5966	67	2506	28	3.5	1.5			8+		78	.77	104	62	42
328		27	28	#	1		PP	6					5.5	9300	590	6045	65	1604	28	4	2	1		3+		85	.76	136	84	52
329			24	—			P	.05		0			4.8	9500	510	6175	65	2850	30	3	1.5	5		3+		83	.85	128	80	48
330		25	21	—			P	.05					3.5	7450	470	4842	65	2458	33	2				+		85	1+	146	84	62
331			20	—			P	.06					5.0	8500	590	3825	45	4420	52	2	1			3+		88	.87	131	82	49
332		26	20	—			P	.04					4.8	7450	650	4301	58	2905	29	2	1			4+		87	.89	140	82	58
333			40	#	0		P	4					5.0	9750	520	5947	61	3510	36	2	1			3+		93	.91	128	76	52
334	23		26	#	2		P	1.06					5.4	6900	780	4209	61	2415	35	3				10+		88	.80	146	84	62
335	4	21	25	#	2		P.V.E. L.	4					5.2	11850	430	6752	57	4621	39	3	.5	.5		3+		75	.72	138	74	64
336		23	36	#	0		P	3					5.4	5950	900	2975	50	2677	45	3	2			10+		90	.83	108	62	46
337			33	#	2		P	7					4.9	7100	690	3408	48	3266	46	4	2			3+		88	.88	116	74	42
338		27	18	—			P	1.01					6.0	7550	800	4454	59	2792	37	1.5	2.5			2+		80	.65	116	74	42

Physical examination number	Albumin	Sugar	Casts	Cylindroids	W.b.c. or pus cells in urine	R.b.c. in urine	Epithelial cells in urine	Oxalate crystals	Urate crystals	Loss of weight	Poor appetite	Digestive disturbances	Constipation	Headache	Dizziness on exertion, on stooping, etc.	Coryza	Post-nasal irritation	Bleeding (N-nasal)	Dyspnea on exertion or otherwise	Rash from cleaner, etc.	Blue line on gums
3					#	#										#		N		#	
16					#																
44		Tr.										#	#			#					#
45														#	#						
46	Tr.					#	#														#
47										#	#	#									#
49																					
50																					
51					#																
54																					
55					#				#				#		#				#		#
56														#					#		
57	Tr.				#					#											#
58	Tr.				#		#													#	
59	Tr.				#	#	#			#				#							
67					#G								#		#				#		
75												#									
76						#															
77					#							#									
78																					
79					G		#		#												
80					#		#														
81												#						N			
82											#	#									
83																					
84					#G																
85														#				N			
86					#					#		#		#							
87					#G															#	
88					#G									#	#						
89					#																
90																		N		#	
91					G																
92					#																
93					#																
94																					
95																					#
96					#																
97						#															
98											#	#			#						
115																		N			
116			no sample		G																
118								#													
119																					
120																					
121					G	#															
122	Tr.																				
123										#		#	#	#	#				#		
124					#							#	#	#	#					#	#
125	Tr.																				
126																					
127					#																
128					#																
129		no sample																			
130					#							#		#	#		#		#		
131																					
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136																					
137					#								#	#							
138					#								#	#							
140	Tr.				#																
141					G						#									#	
142					#		#														
143	Tr.			#									#	#							
144																					
145	#				#	#	#														
146										#	#	#	#	#	#						
147	Tr.				#		#														
148																					
149																					
150																					
152																					
170		no sample								#	#	#									
176					#								#	#							
177					#															#	
178					#																
179	Tr				#																
180					#	#															
181					#G		#														
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184					#																
185																					
186																					
187													#								
188					#G								#	#			N				
189		no sample												#							
190		no sample			G						#	#	#	#	#						
248		no sample								#			#	#							
249																					
250					#															#	
251					#																
252					#									#							
253														#							
254		Tr.																			
255					G										#	#					
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279																					
281							#														
282																					
283																					
285		no sample												#							
286		no sample																			
289		no sample										#		#							
290		no sample										#									
293		no sample																	#		
294		no sample																	#		
297		no sample																			
299		no sample																			
301					G																
303																					
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322														#	#						
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Physical examination number	Other symptoms	Infections in last 5 yrs. before starting to spray	Infections since spraying	Previous related occupations	Other remarks	Alcoholic use (1—occasional, 2—moderate, 3—heavy)	Use of tobacco (1—irregular, 2—moderate, 3—heavy)
3	eyes blur, fingers numb			putty 2 yrs.	irregular heart	1	1
16					polyuria, burning with paint		1
44	gastric pain				polyuria, nocturia		1
45	eyes irrit., eyes pale			truck	polyuria, nocturia	2	2
46						2	2
47	hands tingle	typhoid			nocturia		
49	nasal irritation			truck 4/12 yr			
50	eyes pale				intestinal worms		
51	hands tingle						
54					cleans booth	2	1
55	bronchitis					3	2
56				truck 2 yrs.		2	1
57	eye irrit., hands tingle			truck 2 yrs.	mitral murmur; oppression	3	3
58				sanding 7 yrs.	nocturia	3	3
59	eye irrit., hands tingle			sanding		2	3
67	eye irrit., mitral murmur		carbuncles	painter 7 yrs	nocturia, lead colic 12 yrs. ago; prefers brush		
75							2
76				sander 3½ yrs.		2	2
77						2	2
78							3
79				truck 4/12 yr	glaze 7 yrs. helper		2
80						2	2
81	tingling	malaria				2	2
82						2	1
83					polyuria	2	
84	eye irrit.					3	2
85	hands tingle					3	1
86	tingling		influenza			3	1
87					house painter	3	2
88				painter 9 yrs.	house painter		
89	eye irrit.			painter 3 yrs.	house painter		2
90	eye irrit.				house painter	3	3
91				truck ½ yr.		2	3
92						2	1
93						2	2
94				truck ½ yr.		1	
95				truck ½ yr.	polyuria	2	1
96				helper 4/12 yr.			1
97						1	1
98	eye irrit.			truck 4/12 yr.	faint spells	1	2
115				truck		2	3
116				truck 4/12 yr.		2	2
118				painter 11¼ yrs.	house painter		2
119	pale		malaria; typhoid		house painter	2	
120					house painter	1	2
121			influenza	brush painter ½ yr.	house painter	1	3
122				painter 1 yr.	house painter		2
123	stomach trouble			painter 2/12 yr.	house painter	1	1
124	eye irrit., tingling				stomach pains hot spells		
125		influenza		truck 7/12 yr.		1	3
126				truck 1 yr.		1	3
127	eye irrit.			truck ⅓ yr		2	
128	nervous	influenza		truck ¼ yr		1	3
129	eye irrit., hay fever	mumps				1	3
130	cough	malaria, pneumonia				1	2
131				truck 3/12 yr.;			
132				acid line 9/12 yr.			
133				acid line 1/12 yr.		2	2
134	eye irrit.					—	—
135							1
136						1	
137						1	3
138	eye irrit., oppression			sand and glaze 10/12 yr.	leaded while sanding	1	2
140	aortic systolic murmur			sand, truck 4/12 yr.		2	3
141				putty glaze 2 yrs.	polyuria, nocturia	1	3
142	weak extensors					1	1
143	eye irrit.						
144	eye irrit.					1	3
145	eye irrit.				polyuria, nocturia		3
146	eye irrit., tingling	influenza, pneumonia			chilly; polyuria, forgetful		
147							1
148						1	3
149				truck 5/12 yr.		1	1
150				painter 2 yrs.		1	1
152					away 7 mo. on acc. of gastric pains	1	3
170	numbness						
176	eye irrit.	typhoid		painter 7 yrs.	last lead sprayed 3 mo. ago, house painter		1
177	eye irrit.				last lead sprayed 1 2 yrs. ago, house painter	1	1
178					no lead, house painter	1	1
179	eye irrit.			lacquer spray 5/12 yr.		1	1
180	eye irrit.			lacquer spray 5 yrs.	painter 1 yr.		
181				truck 2 yrs.		1	
182				truck 1½ yrs.		1	
183				truck 2 yrs.		1	
184							
185	eye irrit.			truck 1 yr.		1	
186			pneumonia			2	1
187						2	1
188						2	2
189	eye irrit.		gonorrhea, chancroid tonsillitis	truck 3 yrs.		1	1
190					burning urine	1	2
248	eye irrit., chilly, faint	diphtheria	diphtheria		house painter, sprays lead, polyuria, nocturia	1	2
249				painter 2 yrs.	house painter, little lead used		
250				helper 9/12 yr.	house painter, sprays lithopone & lead		
251	eye irrit.			painter 3 yrs.	house painter, sprays lithopone & lead	2	3
252					house painter, supervisor, lithopone & lead	2	
253	frontal sinusitis				house painter, no lead for 1½ yrs.		
254					house painter, no lead for 1½ yrs.		
255				painter 7/12 yr	house painter, no lead for 5 mo.	1	3
256	eye irrit.				nocturia, polyuria	1	2
257	eye irrit.				heavy and dull	1	2
258	eye irrit.			sand 2 wks.		2	2
259	knee reflex weak	pneumonia		truck 2 yrs.		2	1
260	eye irrit.					2	2
261	eye irrit.			sprayed lacquer 2 yrs.			
262	on hands and in groin	appendicitis			boil on arm	2	
263						2	
279	tingling				oil sanding 1 yr.	1	
281			bronchitis	truck ½ yr.		1	2
282				truck	polyuria	1	1
283							
285					house painter, no lead for 3 mo.	2	1
286					lead 1 mo. ago		
289					polyuria, nocturia		
290				brush 3 yrs.	polyuria		
293	hand tingles	typhoid			chilly	2	2
294							
297	weak extensors			painter 2 yrs.	Bell's paral. 3 yrs. ago	1	1
299				painter 8 yrs.		2	2
301				varnish rub 3½ yrs		2	1
303							
307							
322				painter 10½ yrs	prefers brush; little lead sprayed for past yr. not spray lead		1
323	gastric ulcer			painter 2 yrs.	½ time brush, prefers spray		1
326	exaggerated reflex				½ time brush, lead 4-5 mo. in year		2
327						2	3
328				paint 1 yr	¼ time brush	2	3
329		typhoid, pneumonia					
330					lead outside	2	3
331	exaggerated reflex				lead outside; sprayed lead 10 days ago		1
332	tonsillitis			painter 20 yrs	prefers spray	1	2
333	tonsillitis				leaded previously		
334	tonsillitis					1	2
335	eye irrit.						
336		malaria in 1914			sprayed lead recently	2	2
337						2	2
338	gastric pain			painter 1½ yrs.	prefers brush, leaded recently	2	1

Table C 3—VITREOUS ENAMEL SPRAYERS ON SHEET METAL

Physical examination number	Industry number	Plant Number	Age	Married# or Single—	Number of children	Male or Female F	Materials sprayed	Years spraying	Air velocity n ft. per min.	Related occupation	Mil. ¼ unit particles per cu. ft. air	Mil. r. b. c. per cu. mm. blood	W. B. C. per cu. mm. blood	Ratio; w.b.c. to no. r.b.c.	Calculated polomorphonuclear count	% Polomorphonuclear count	Calculated lymphocyte count	% Lymphocyte count	% Large mononuclear count	% Cosinophile count	% Basophile count	Stipple cells per 100,000 r.b.c.	Basophilic aggregations (McCord)	Number of w.b.c. counted in hundreds	% Hemoglobin	Color index	Systolic blood pressure	Diastolic blood pressure	Pulse pressure	Albumin	Sugar	Casts	Cylindroids	W.B.C. or pus cells	R.B.C.	Epithelial cells	Oxalate crystals	Urate crystals	Loss of weight	Poor appetite	Digestive disturbances	Constipation	'Ieadache	Dizziness on stooping or otherwise	Coryza	Post-nasal irritation	Bleeding (N-nasal)	Dyspnea on exertion or otherwise		Other symptoms	Infections in last 5 yrs. before starting to spray	Infections since spraying	Previous related occupations	Other remarks	Use of alcohol (1—occasional, 2—moderate, 3—heavy)	Use of tobacco (1—irregular, 2—moderate, 3—heavy)	
219	21	7	20	/			VES	.08	36			3.9	12150	320	5467	45	6439	53	1	.5	.5	66		4	74	.93	142	88	54														#	#				#			appendicitis		grinding frit	sprays castings one day a wk.	1	2	R. p. b. P
220			24	#	1		VES(C)	4	30		24	4.1	9300	440	5487	59	3255	35	3	2	1	0	4+	2	74	.89	128	88	40												#		#	#				#		yolyuria, nocturia weakness			castings until 4 mo. ago	lead colic 3 yrs. ago	1	1	R. p. b. P. /
221			22	/			VES(C)	5			13	4.6	12650	360	7337	58	4680	37	3	2		0		3	85	.91	136	88	48												#									olyuria, nocturia, diarrhea weekly			castings over 1 yr. ago	brushing	2	2	
222			23	/			VES	.05		brushing		4.5	8900	500	5340	60	3115	35	2	3		0		2	84	.92	116	82	34										#								H					tonsillitis			2	1	
223			19	/			VES	.07				4.0	7150	670	4075	47	2717	38	4	1				3	78	.81	118	84	34														#											polyuria	1		
225			24	#	0		VES	.07				5.0	7750	650	5580	72	1937	25	2	1				2	79	.78	142	78	64					#					#	#						#				chilly, gastric pain				polyuria			
229		8	19	/		F	VES(C)	1.06	240		20	3.9	7650	520	4666	61	2677	35	3	1		366	10+	4	70	.87	98	72	26					#					#	#	#		#	#				#		eye irrit.		tonsillitis	castings before	gastric pain with castings			
230			22	/		F	VES(C)	5				4.3	6050	720	4477	74	1270	21	2.5	2.5				2	80	.91	130	88	42	Tr.				#		#																castings at times		1		
231			19	/		F	VES(C)	.07	120		11 19	4.3	8650	500	5709	66	2681	31	2	1			10+	2	85	.97	126	88	38										#	#	#	#	#			#				numb hand	diphtheria						
233			18	/		F	VES	1.06	98		6.6 3.7	4.1	10150	400	7003	69	2639	26	4.5	.5		0		2	78	.94	114	76	38																											
234			18	/		F	VES	.08				4.0	9800	410	6468	66	2940	30	3	1				2	82	1+	118	78	40																											
235			20	/		F	VES	1.06				4.0	10000	400	6100	61	3700	37	2					2	83	1+	130	82	48														#			#						bronchitis					
236			18	/		F	VES(C)	1				4.1	8950	460	5638	63	2864	32	4.5	.5		225		2			108	70	38												#												castings 1st 6 mo.	gastric pain with castings			
237			18	/		F	VES	.09	74		4.2	4.2	6650	640	4189	63	2261	34	3					2	80	.93	126	78	48									#																		
238			21	/		F	VES	4.06				4.3	10000	430	6200	62	3400	34	3	1		28		2	92	1+	112	68	44							#																				
240		9	22	#	0	F	VES	.08			100 170	4.5	7100	630	3976	56	2840	40	3	1		218		2	80	.88	118	80	38					#																						
241			23	/		F	VES	1				4.5	7550	600	4756	63	2567	34	2	1				2	81	.88	112	78	44											#	#					#				eye irrit.				quit work for 3 mo. on acc. of abd. pain			
242			27	#	1	F	VES	.05				3.2	5900	550	3471	59	2292	38	1	1	1	85		2	80	1.2	110	76	34					#																							R. p. b. P. /
243			34	#	0	F	VES	.06				4.2	7000	600	4760	68	1961	28	3	.5	.5	25		2	75	.89	118	85	33					#								#	#			#				eye irrit.							
244			22	#	0	F	VES	1			110 140	4.2	8700	490	5046	58	3305	38	2	2		0		2	70	.81	130	78	52					#								#								throat sore							
341		28	35	#	0	F	VES	4.06		dusting		4.4	8340	530	4170	50	3836	46	2.5	1	.5		2+	2	75	.84	112	76	36	no sample												#		#				#		menses irreg. pain		bronchitis		boils			P. /
343			22	#	0	F	VES	3				5.0	6950	720	4100	59	2502	36	3	1.5	.5		3+	3	45	.44	108	64	44	no sample									#				#	#				#		menorrhea	beef tape worm			incisors worn cough, expectoration			P. /
344			44	#	2	F	VES	3.06		dusting	27 34	4.7	6900	680	4209	61	2277	33	3	1.5	1.5		2+	2	78	.82	132	84	48	no sample																		#		numb hand		rheumatism	core cleaner 16 mo.				P.
345			24	#	0	F	VES	5				4.5	12000	370	7800	65	3840	32	2	1			+	2	75	.83	108	78	30	no sample											#	#		#			N	#			lung trouble						silicosis 2nd stage
346			18	#	0	F	VES	1.05				4.8	8850	540	5310	60	3274	37	2	1			2+	2	77	.79	110	74	36	no sample										#	#	#								dysmenorrhea	tonsillitis	tonsillitis					P. /
347			28	/			VES	5				5.2	7600	720	4788	63	2660	35	1.5		.5		2+	4	80	.72	129	74	55	no sample											#			#										foreman	1	1	P. /
26			604 23+	11	4	19F		49.03 1.10+																																																	

Table C 4 VITREOUS ENAMEL SPRAYERS ON CASTINGS

Physical examination number	Industry number	Plant number	Age	Married# or Single/	Number of children	Male or Female—F	Materials sprayed	Years or months spraying (yrs. as whole numbers, months as decimals)	Air velocity in ft. per min.	Mg. lead per grm. feces	% Total lead in enamel	% Soluble lead in enamel	Mil. ½ unit sized particles per cu. ft. air	Mil. r.b.c. per cu. mm. blood	W.B.C. per cu. mm. blood	Ratio; one w.b.c. to no. r.b.c.	Calculated polymorphonuclear count	% Polymorphonuclear count	Calculated lymphocyte count	% Lymphocyte count	% Large mononuclear count	% Eosinophile count	% Basophile count	Stipple cells per 100,000 r.b.c.	Basophilic aggregations (McCord)	Number w.b.c. counted by hundreds	% Hemoglobin	Color index	Systolic blood pressure	Diastolic blood pressure	Pulse pressure	Albumin	Sugar	Casts	Cylindroids	W.B.C. or pus cells	R.B.C.	Epithelial cells	Oxalate crystals	Urate crystals	Loss of weight	Poor appetite	Digestive disturbances	Constipation	Headaches	Dizziness on stooping or otherwise	Coryza	Post-nasal irritation	Bleeding (N-nasal)	Dyspnea on exertion or otherwise	Blue line on gums	Other symptoms	Infections in last 5 yrs. before spraying	Infections since spraying	Previous related occupations	Other remarks	Use of alcohol (1—occasional, 2—moderate, 3—heavy)	Use of tobacco (1—irregular, 2—moderate, 3—heavy)	
218	21	7	26	#	1		VEC	1.06	I		26 2.8	.7 .4	23 25	4.3	8900	480	4272	48	4272	48	2.5	1	.5	160	4+	2	69	.80	116	74	42					G							#	#		#		#		#		pallor, frontal sinusitis				gassed in France			
224			19	/			VEC	.08	I					4.8	8700	550	2784	32	5481	63	3.5	1.5		0	8+	4	80	.82	142	74	68							#					#		#										sheet for 6½ mo.		1		
226		8	22	/			VEC	2	I	.9			5.6	4.6	9350	490	5610	60	3559	37	3			909	10+	2	82	.88	142	82	60																					gastric pain		tonsillitis			1	2	
227			24	/			VEC	2.06	H	0				4.4	9300	470	5776	62	3069	33	3.5	1.5		400	10+	2	72	.81	112	70	42											#	#		#							lumbar pain							
228			22	/			VEC	1.03	I		23	20	4.9	fainte	d, no b	lood ex	amina	tion							0				118	68	50	no	sam	ple			G					#	#			#		#		#		eye irrit. chilly tingling, formication			molder 9 yrs.		3	2	
231			19	/			VECS	.07	I				19	4.3	8650	500	5709	66	2681	31	2	1			0	2	85	.97	126	88	38										#	#	#	#	#			#											
232			19	/			VECS	3	H				11	4.4	12650	340	8222	65	3542	28	5	1	1		0	2	78	.88	144	70	74	no s	amp	le							#		#									boil on arm		tonsillitis	also brush	frequent stomach upset	1		
239		9	25	/		F	VECS	9	H					4.2	8800	470	5104	58	3432	39	2.5	1.5			3+	2	75	.89	130	88	42													#		#						dysmenorrhea, 2nd stage silicosis		pleurisy		gen. poor health			
245			24	/			VEC	1.03	I	120			100	4.3	8600	500	5070	59	3354	39	1.5	1	.5	571	10+	3	63	.73	144	88	56																								sand blast 6 mos.	P. / R. p. b. infiltr. root &			
246							VECS	1.06	I				1800	night	man n	o phys	ical ex	amina	tion						0																															P. / R. p.b. infiltr.			
247							VECS	1.06	I					night	man n	o phys	ical ex	amina	tion						0																															No X-ray			
308	21	19	29	/			VEC	2	I	20				4.5	6850	650	3151	46	6	2					8+	3	92	1+	122	88	34					G																abdominal pain				puttier miliary calcareous areas			
309			50	/			VEC	2						4.5	6700	680	3886	58	2546	38	2	2			10+	2	65	.71	158	92	66																									mixer P. / M. /	2	1	
310			26	#	1		VEC	1.03	I I	17			.31	4.6	6950	660	4309	62	2293	33	2	2.5	.5		2+	2	86	.86	106	64	42													#	#	#								measles	burn, putty and spray	P. / M. /		3	
311			27	/			VEC	2	I					4.5	9450	480	5953	63	3118	33	2	1.5	.5		3+	2	82	.90	144	70	74																					pallor, erythmia	influenza	measles		booth cleaner P. / M. p.b.			
312			23	#	0		VEC	2.06	H	2	3.8	3.8		4.7	5300	890	3286	62	1696	32	3	2	1		8+	2	74	.78	122	74	48																		N			exag. reflex				P. / M. /			
313			26	#	0		VEC	2	I	21			.54	4.2	7350	580	4336	59	2646	36	3	2			6+	2	82	.96	130	72	58										#									#		pain in side, cough			paint spray 1 yr.	winter bronch. P. / M. p.b.	1	2	
314			22	#	1		VEC	2.06	H					5.0	8100	620	5760	70	1944	24	2	4			4+	2	85	.83	124	96	28										#	#				#	#					winter bronchitis		measles sinusitis	sand blast ½ yr. paint spray 4-12 yr.	P. / M. linear	1	3	
315			36	#	2		VEC	2.06	H					4.8	8800	550	5808	66	2552	29	3.5	1	.5		3+	2	78	.80	130	78	52														#					#				pneumonia	assistant foreman	P. suspicious	1	3	
316			33	#	1		VEC	2	I					5.4	7200	750	4896	68	1800	25	4	2.5	.5		2+	2	78	.71	118	88	30										#											rheumatism		tonsillitis		P. / M. /		1	
317			23	#	0		VEC	1.06	I					4.9	12700	390	9144	72	3175	25	2	1			2+	2	80	.80	118	78	40																					slow reflex				burner P. / M. /	1	2	
318			29	#	0		VEC	3	H					5.4	6550	830	3930	60	2292	35	3.5	1.5			6+	2	85	.77	104	64	40															#	#					sinusitis		influenza		supt., healed tuberc.			
319							VEC	1.06	I						night	spraye	r no ph	ysical	examin	ation												no s	amp	le																						P. / M. /			
320							VEC	1.06	I						night	spraye	r no ph	ysical	examin	ation												no s	amp	le																						P. / M. /			
321							VEC	1.06	I						night	spraye	r no ph	ysical	examin	ation												no s	amp	le																						P. / M. /			
339		28	19	/			VEC	1	I					5.5	7850	700	5216	69	2298	28	2	1			2+	2	90	.81	122	76	46	no s	amp	le																		reflex slow	scarlatina			P. / M. /			
340			21	/			VEC	1	I		13	11	2	5.7	9250	610	6937	75	1850	20	4	1			2+	3	90	.78	122	76	46	no s	amp	le																						P. / M. /			
342			40	#	0	F	VEC	4	H				2.2	3.8	8950	420	5728	64	2953	33	2	1			10+	2	60	.78	122	74	48	no s	amp	le												#	#					reflex slow cholecystectomy				P. / M. / pale silicosis 2nd stage		1	
348			45	#	2		VEC	7	H					4.7	6650	720	3857	58	2327	35	3	3.5	.5		3+	2	92	.96	132	78	54	no s	amp	le							#					#						reflex exaggerated				foreman, P/		2	
349	21	29	50	#	0		VEC	2.06	H					5.1	6650	760	4189	63	2261	34	3				10+	2	69	.67	134	76	58	no s	amp	le												#				#		nocturia					2	2	
350			40	#	2		VEC	1	I				1.1	5.0	9450	530	6426	68	2268	24	2	5	1		10+	2	80	.78	124	74	50	no s	amp	le												#				#		reflex slow asthma 4 yr.			sand blast 1 yr.	leg pains	2	1	
351			32	#	2		VEC	.05	L					3.8	7450	510	4917	66	2309	31	1	1.5	.5		8+	3	70	.92	112	80	32	no s	amp	le																		nocturia weak extensors				carrier off 1½ yrs.	2	1	
352			24	#	0		VEC	.6/52	L				1.6	4.9	6450	760	2773	43	3289	51	3	2.5	.5		6+	3	80	.81	110	68	62	no s	amp	le							#	#	#	#	#							tingling, tic				in plant 1 yr. colic 2 wks. ago		2	
353			40	#	2		VEC	5	H					3.8	5750	660	4197	73	1322	23	2	1	1		3+	2	54	.70	128	80	48	no s	amp	le							#					#						gastric ulcer				mixes, cleans brushing			
354			42	#	2		VEC	3.06	H					4.6	13200	340	8844	67	3696	28	2.5	1.5	1		10+	3	78	.84	138	86	52	no s	amp	le																								1	Silicosis 1st stage

Table D—SYMPTOMOTOLOGY

(Table completed on following page)

	No.	% Hemoglobin	Color Index	Infections before		Infections since		Lost Weight		Poor Appetite		Digestive Disturbances		Constipation	
Penna.															
Shellac	7			4	55	0								1	14
Varnish	34			17	50	7	20	1	3	4	11	8	23	5	14
Paint	81			40	50	15	18	4	5	4	5	19	23	11	13
Lacquer	127			43	35	12	9	4	3	18	14	26	20	16	12
Subst. Shellac and Stain	15			6	40	4	26					1	6	2	13
N. S. C.															
Lacquer—total	164	82	.89	12	7	18	11	27	12	16	10	22	13	25	15
Lacquer No. 1	23	76	.84	3	1	3	1	5	22	7	30	7	30	5	22
Lacquer No. 2	41	76	.85	4	10	5	12	5	12	4	10	3	7	8	20
Lacquer No. 4	17	82	.92			2	12	3	18	1	6	2	12	1	6
Lacquer No. 5	25	86	.96	2	8	3	12	5	20	2	8	2	8	2	8
Lacquer No. 6	27	91	.96			6	22					6	22	1	4
Lacquer No. 17	16	75	.86	2	12			2	12	2	12	1	6	2	12
Lacquer No. 18	11	84	.87	1	9			1	9			1	9	3	27
Lacquer No. 22+survey crew	4	86	.85												
Lacquer to 2 mo.	6	82	.90												
2+to 4 mo.	10	77	.86					1	10	2	20	1	10	2	20
4+to 6 mo.	15	76	.85					1	7	1	7	2	13		
6+to 12 mo.	34	80	.87					3	9	3	9	4	12	4	12
1+to 2 yrs.	29	78	.82					4	14	6	21	6	21	5	17
2+to 4 yrs.	52	77	.86					6	12	3	6	4	8	6	12
4+to 6 yrs.	10	77	.79					4	40	1	10	4	40	3	30
6+yrs.	7	75	.86					2	28			1	14	2	28
Undercoats and Paints	135	76	.84	10	7	13	9	9	7	8	6	25	18	11	8
Undercoats	34	73	.81	2	6	3	9	5	15	1	3	7	20	5	15
Paints—no lead	20	78	.89	1	5	2	10	2	10			2	10	1	5
Paints—lead	19	87	.84	4	21	1	5	1	5	1	5	2	10	3	16
Primer	21	76	.83	3	16	1	5	2	9	1	5	4	19	3	14
Rough Stuff	17	76	.85	1	6					1	6	3	18		
Slush	8	73	.81	2	25	1	12			1	12	3	37	3	37
Oxide	7	78	.88	1	14										
Glaze	13	76	.85							1	8	4	31		
Ground	4	80	.83					1	25	1	25	1	25		
Filler	2	63	.89							1	50				
to 2 mo.	9	74	.79							1	11	1	11		
2+to 4 mo.	11	75	.81							1	9	1	9	1	9
4+to 6 mo.	14	77	.84												
6+to 12 mo.	21	74	.82					3	14	2	9	3	14	2	9
1+to 2 yrs.	25	77	.84					1	4	3	12	9	36	3	12
2+to 4 yrs.	37	79	.87					4	11	1	3	7	18	3	8
4+to 6 yrs.	11	70	.85												
6+to 10 yrs.	8	68	.79					1	12			4	50	2	25
12 yrs.	1	60	1.00												
Vitreous Enamels.															
Penna.	76			41	54	29	38	7	9	4	5	8	10	11	14
N. S. C. sheet	26	77	.88	4	15	4	15	5	19	5	19	9	34	6	23
N. S. C. castings	35	77	.82	2	5	9	26	8	23	5	14	7	20	5	14

	Headache		Dizziness		Nasal or Post-nasal Irrit.		Bleeding		Dyspnea		Dermatitis		Lead Line		Pharyngitis, etc.	
Penna.																
Shellac					1	14	1	14								
Varnish	11	32	8	23	6	17			4	11	1	3				
Paint	18	22	6	7	7	8	3	3	7	8	2	2				
Lacquer	30	23	29	23	13	10	5	4	14	11	1	1				
Subst. Shellac and Stain	5	33	5	33	1	7			3	20						
N. S. C.																
Lacquer—total	30	18	30	18	28	17	13	8	20	12	8	5	1	.6	5	3
Lacquer No. 1	8	35	6	26	12	52	3	13	5	22	4	17			1	4
Lacquer No. 2	4	10	9	22	11	27	4	10	7	17	2	5			2	5
Lacquer No. 4	5	29	3	18	3	18					1	6			1	6
Lacquer No. 5	1	4	5	20	2	8			2	8						
Lacquer No. 6	7	26	3	11			1	4	2	7						
Lacquer No. 17	5	37	3	19			2	12	2	12						
Lacquer No. 18			1	9	1	9	2	18	2	18			1	9	1	9
Lacquer No. 22+survey crew																
Lacquer to 2 mo.																
2+to 4 mo.	1	10	2	20	1	10			1	10	1	10				
4+to 6 mo.	3	20	1	7					4	27						
6+to 12 mo.	5	15	5	15	6	18	6	18	3	9	2	6			1	3
1+to 2 yrs.	5	17	4	14	7	24	2	7	7	24					2	7
2+to 4 yrs.	13	25	10	19	11	20	3	6	3	6	4	8			1	2
4+to 6 yrs.	1	10	5	50	4	40			1	10	1	10	1	10	1	10
6+yrs.	2	28	3	43	1	14	1	14	1	14						
Undercoats and Paints	24	18	18	13	5	4	6	4	10	7	4	3	8	6		
Undercoats	7	20	5	15	2	6	2	6	3	9	3	9	7	20		
Paints—no lead	4	20	3	15	1	5	1	5	3	15			1	5		
Paints—lead	2	10	4	21	3	16										
Primer	2	9	3	14			2	9			1	5	2	9		
Rough Stuff	3	18	2	12					1	6						
Slush	3	37	3	37	1	12	1	12	2	25			1	12		
Oxide	2	28							1	14						
Glaze	1	8							2	15						
Ground							1	25								
Filler									1	50						
to 2 mo.									1	11			1	11		
2+to 4 mo.			1	9							1	9				
4+to 6 mo.	2	14							1	7						
6+to 12 mo.	3	14	3	14	2	9	2	9	2	9	1	6	4	19		
1+to 2 yrs.	5	20	5	20	2	8	1	4	3	12			1	4		
2+to 4 yrs.	5	15	6	16	1	3	1	3	1	3	2	5	2	5		
4+to 6 yrs.	2	18	1	9					1	9						
6+to 10 yrs.	6	75	2	25			1	12	3	37						
12 yrs.	1	100					1	100								
Vitreous Enamels.																
Penna.	8	10	12	16	10	13			13	17			1	1		
N. S. C. sheet	8	31	7	27	5	19	2	8	7	27					1	4
N. S. C. castings	6	17	11	31	7	20	1	3	6	17			1	3		

	Eye Irritatis		Polyoria		Nocturia		Burning Urine		Chilliness		Faint, Languid, Tired, Weak, etc.		Tingling or Formication		Cardiac Murmurs	
Penna.																
Shellac	1	14			1	14										
Varnish	3	9	4	11			2	6							1	3
Paint	2	2	7	8	7	8	1	1			1	1				
Lacquer	2	1	4	3	6	5	1	1	3	2	2	1	2	1	5	4
Subst. Shellac and Stain	2	13													1	7
N. S. C.																
Lacquer—total	46	28	18	11	13	8	6	3	3	2	10	6	6	3	4	2
Lacquer No. 1	8	35	7	30	2	8	2	8	2	8	1	4			1	4
Lacquer No. 2	14	34	3	7	6	15	1	2			2	5			2	5
Lacquer No. 4	3	18	3	18	1	6	1	6			2	12	1	6		
Lacquer No. 5	11	44	1	4	2	8	2	8	1	4	5	20	2	8		
Lacquer No. 6	7	26	2	7	1	4							1	4		
Lacquer No. 17	2	12	1	6	1	6							2	12		
Lacquer No. 18	1	9	1	9											1	9
Lacquer No. 22+survey crew																
Lacquer to 2 mo.	1	17	1	17												
2+to 4 mo.	3	30	2	20							1	10				
4+to 6 mo.	4	27	1	7	1	7							1	7		
6+to 12 mo.	9	26	2	6	2	6	1	3	1	3	4	12	1	3	1	3
1+to 2 yrs.	7	24	1	3	1	3			1	3	2	7	1	3		
2+to 4 yrs.	18	35	7	13	4	8	3	6	1	2	2	4	2	4	2	4
4+to 6 yrs.	2	20	4	40	4	40	2	20			1	10	1	10		
6+yrs.	2	28			1	14									1	14
Undercoats and Paints	31	23	10	7	9	7	2	2	3	2	3	2	10	7	2	2
Undercoats	11	32	6	18	7	20	1	3					6	18	2	6
Paints—no lead	6	30	1	5	1	5										
Paints—lead	2	10	1	5	1	5			1	5	1	5				
Primer	7	33	1	5	1	5					1	5	3	14		
Rough Stuff	3	18	2	12	1	6			1	6	1	6			1	6
Slush	4	50					1	12					2	25		
Oxide	2	28														
Glaze	1	8	1	8	1	8										
Ground																
Filler	1	50														
to 2 mo.	1	11	1	11	1	11									1	11
2+to 4 mo.	4	36													1	9
4+to 6 mo.	1	7	1	7									1	7		
6+to 12 mo.	3	14	1	4	2	9							3	14		
1+to 2 yrs.	5	20					1	4	1	4			1	4		
2+to 4 yrs.	11	30	5	15	4	11	1	3	2	5	3	8	3	8		
4+to 6 yrs.	2	18	1	9	2	18										
6+to 10 yrs.	4	50	1	12									1	12		
12 yrs.													1	100		
Vitreous Enamels.																
Penna.															5	7
N. S. C. sheet	3	11	3	11	2	8			1	4	1	4				
N. S. C. castings	1	3			2	5			1	3			2	5		

Black figures represent number of cases.
Light figures represent percentages in each group (to the nearest whole number, except .6=⅙ of 1%).
Apparent discrepancies in undercoat groups due to men spraying two or more coats.
One general undercoat sprayer not listed in any one group, but included in total.

Table D—SYMPTOMOTOLOGY

(Concluded from preceding page)

	No.	% Hemoglobin	Color Index	Irregular Heart		Numbness		Heavy, Dopy, Forgetful		Chest Oppression		Nervous		Pallor		Cough	
Penna.																	
Shellac	7																
Varnish	34			1	3												
Paint	81							1	1								
Lacquer	127			3	2	1	1					2	1			1	1
Subst. Shellac and Stain	15			1	7												
N. S. C.																	
Lacquer—total	164	82	.89	5	3	5	3	3	2	4	2	3	2	1	.6	8	5
Lacquer No. 1	23	76	.84	2	8	3	13	1	4	1	4					4	17
Lacquer No. 2	41	76	.85	1	2	1	2	1	2	2	5	1	2			2	5
Lacquer No. 4	17	82	.92									1	6	1	6	1	6
Lacquer No. 5	25	86	.96					1	4	1	4	1	4			1	4
Lacquer No. 6	27	91	.96	2	7												
Lacquer No. 17	16	75	.86														
Lacquer No. 18	11	84	.87			1	9										
Lacquer No. 22+survey crew	4	86	.85														
Lacquer to 2 mo	6	82	.90	1	17												
2+to 4 mo	10	77	.86													1	10
4+to 6 mo	15	76	.85	2	13												
6+to 12 mo	34	80	.87	1	3	1	3	1	3							1	3
1+to 2 yrs	29	78	.82	1	3	1	3			1	3					3	10
2+to 4 yrs	52	77	.86			1	2	2	4	2	4	2	4	1	2	2	4
4+to 6 yrs	10	77	.79			1	10			1	10					1	10
6+yrs	7	75	.86			1	14					1	14				
Undercoats and Paints	135	76	.84	1	1	2	2			2	2			3	2	1	1
Undercoats	34	73	.81	1	3	1	3			1	3			3	9		
Paints—no lead	20	78	.89														
Paints—lead	19	87	.84														
Primer	21	76	.83														
Rough Stuff	17	76	.85														
Slush	8	73	.81													1	12
Oxide	7	78	.88														
Glaze	13	76	.85							1	8						
Ground	4	80	.83			1	25										
Filler	2	63	.89														
to 2 mo	9	74	.79														
2+to 4 mo	11	75	.81														
4+to 6 mo	14	77	.84														
6+to 12 mo	21	74	.82	1	4	2	9									1	4
1+to 2 yrs	25	77	.84							1	4						
2+to 4 yrs	37	79	.87											3	8		
4+to 6 yrs	11	70	.85														
6+to 10 yrs	8	68	.79							1	12						
12 yrs	1	60	1.00														
Vitreous Enamels.																	
Penna.	76			1	1											1	1
N. S. C. sheet	26	77	.88			2	8									1	4
N. S. C. castings	35	77	.82	1	3							3	8	3	8	1	3

	Bronchitis		Pneumonia		Gastro-Int. Ulcer		Weak Extensors		Neuritis		Diarrhea		Reflex Weak	
Penna.														
Shellac														
Varnish														
Paint	1	1	1	1										
Lacquer	4	3	1	1					3	2	1	1		
Subst. Shellac and Stain	2	13												
N. S. C.														
Lacquer—total	5	3	2	1	1	.6	1	.6	1	.6	1	.6	1	.6
Lacquer No. 1	2	8	2	8										
Lacquer No. 2	2	5			1	2			1	2				
Lacquer No. 4											1	6		
Lacquer No. 5	1	4												
Lacquer No. 6							1	4						
Lacquer No. 17													1	6
Lacquer No. 18														
Lacquer No. 22+survey crew														
Lacquer to 2 mo														
2+to 4 mo	1	10												
4+to 6 mo	1	7												
6+to 12 mo														
1+to 2 yrs			2	7							1	3		
2+to 4 yrs	2	4			1	2	1	2					1	2
4+to 6 yrs	1	10							1	10				
6+yrs														
Undercoats and Paints	1	1	2	2	1	1	2	2					1	1
Undercoats			1	3			1	3						
Paints—no lead														
Paints—lead					1	5								
Primer	1	5	1	5									1	5
Rough Stuff							1	6						
Slush			1	12										
Oxide														
Glaze														
Ground														
Filler														
to 2 mo					1	11								
2+to 4 mo														
4+to 6 mo														
6+to 12 mo	1	4	1	4									1	4
1+to 2 yrs							1	4						
2+to 4 yrs			1	3			1	3						
4+to 6 yrs														
6+to 10 yrs														
12 yrs														
Vitreous Enamels.														
Penna.	4	5							1	1				
N. S. C. sheet	2	8	1	4							1	4		
N. S. C. castings	2	5	1	3	1	3	1	3					4	11

	Reflex Exaggerated		Gastric Pain		Backache, Muscle Pain		Facial Paralysis		Sinusitis		Renal Gravel		Females		Dysmenorrhea	
Penna.																
Shellac																
Varnish					2	6							1	3		
Paint					2	2							4	5	2	50
Lacquer					7	5							11	9	4	36
Subst. Shellac and Stain													2	13		
N. S. C.																
Lacquer—total					2	1					1	.6				
Lacquer No. 1					1	4										
Lacquer No. 2																
Lacquer No. 4					1	6										
Lacquer No. 5																
Lacquer No. 6																
Lacquer No. 17																
Lacquer No. 18											1	9				
Lacquer No. 22+survey crew																
Lacquer to 2 mo																
2+to 4 mo																
4+to 6 mo																
6+to 12 mo																
1+to 2 yrs																
2+to 4 yrs					1	2					1	2				
4+to 6 yrs																
6+yrs					1	14										
Undercoats and Paints	2	2	4	3			1	1	1	1						
Undercoats							1	3								
Paints—no lead									1	5						
Paints—lead	2	10	2	10												
Primer			1	5												
Rough Stuff																
Slush			1	12												
Oxide																
Glaze																
Ground																
Filler																
to 2 mo																
2+to 4 mo	1	9							1	9						
4+to 6 mo																
6+to 12 mo	1	4					1	4								
1+to 2 yrs			2	8												
2+to 4 yrs			2	5												
4+to 6 yrs																
6+to 10 yrs																
12 yrs																
Vitreous Enamels.																
Penna.									1	1			17	22	7	41
N. S. C. sheet			4	15									19	73	3	16
N. S. C. castings	2	5	3	8	3	8			2	5			2	5	1	50

Black figures represent number of cases.
Light figures represent percentages in each group (to the nearest whole number, except .6=⅙ of 1%).
Apparent discrepancies in undercoat groups due to men spraying two or more coats.
One general undercoat sprayer not listed in any one group, but included in total.

TABLE E

Summary of Symptoms

Penna.				
Shellac Sprayers	7	5 complaints or .7	per sprayer,	5 kinds of symptoms
Varnish Sprayers	34	62 complaints or 1.8	per sprayer,	15 kinds of symptoms
Paint Sprayers	81	106 complaints or 1.3	per sprayer,	20 kinds of symptoms
Lacquer Sprayers	127	208 complaints or 1.6	per sprayer,	28 kinds of symptoms
Subst. Shellac & Stain	15	23 complaints or 1.5	per sprayer,	10 kinds of symptoms
N.S.C. Lacquer total	164	374 complaints or 2.2	per sprayer,	36 kinds of symptoms
Lacquer Plant No. 1	23	102 complaints or 4.4	per sprayer,	26 kinds of symptoms
Lacquer Plant No. 2	41	99 complaints or 2.4	per sprayer,	26 kinds of symptoms
Lacquer Plant No. 4	17	36 complaints or 2.1	per sprayer,	20 kinds of symptoms
Lacquer Plant No. 5	22	50 complaints or 2.2	per sprayer,	20 kinds of symptoms
Lacquer Plant No. 6	27	34 complaints or 1.2	per sprayer,	12 kinds of symptoms
Lacquer Plant No. 17	16	26 complaints or 1.6	per sprayer,	13 kinds of symptoms
Lacquer Plant No. 18	11	18 complaints or 1.6	per sprayer,	14 kinds of symptoms
Lacquer up to 2 mo.	6	3 complaints or 0.5	per sprayer,	3 kinds of symptoms
Lacquer 2# to 4 mo.	10	20 complaints or 2.0	per sprayer,	14 kinds of symptoms
Lacquer 4# to 6 mo.	15	22 complaints or 1.4	per sprayer,	12 kinds of symptoms
Lacquer 6# to 12 mo.	34	67 complaints or 1.9	per sprayer,	23 kinds of symptoms
Lacquer 1# to 2 yrs.	29	70 complaints or 2.4	per sprayer,	22 kinds of symptoms
Lacquer 2# to 4 yrs.	52	120 complaints or 2.1	per sprayer,	31 kinds of symptoms
Lacquer 4# to 6 yrs.	10	45 complaints or 4.5	per sprayer,	22 kinds of symptoms
Lacquer 6# to 10 yrs.	7	20 complaints or 2.9	per sprayer,	14 kinds of symptoms
Undercoats & Paints	137	222 complaints or 1.6	per sprayer,	33 kinds of symptoms
Undercoa s	34	89 complaints or 2.6	per sprayer,	24 kinds of symptoms
Paints—no lead	20	27 complaints or 1.35	per sprayer,	13 kinds of symptoms
Paints—lead	19	27 complaints or 1.4	per sprayer,	15 kinds of symptoms
Primer	21	37 complaints or 1.7	per sprayer,	18 kinds of symptoms
Rough coat	17	20 complaints or 1.1	per sprayer,	12 kinds of symptoms
Slush	8	28 complaints or 3.5	per sprayer,	15 kinds of symptoms
Oxide	7	5 complaints or 0.7	per sprayer,	3 kinds of symptoms
Glaze	13	12 complaints or 0.9	per sprayer,	8 kinds of symptoms
Ground	4	5 complaints or 1.25	per sprayer,	5 kinds of symptoms
Filler	2	3 complaints or 1.3	per sprayer,	3 kinds of symptoms
Undercoats & Paints				
up to 2 mo.	9	9 complaints or 1.0	per sprayer,	9 kinds of symptoms
2# to 4 mo.	11	12 complaints or 1.1	per sprayer,	9 kinds of symptoms
4# to 6 mo.	14	6 complaints or 0.4	per sprayer,	5 kinds of symptoms
6# to 12 mo.	21	45 complaints or 2.2	per sprayer,	23 kinds of symptoms
1# to 2 yrs.	25	45 complaints or 1.8	per sprayer,	17 kinds of symptoms
2# to 4 yrs.	37	69 complaints or 1.8	per sprayer,	22 kinds of symptoms
4# to 6 yrs.	11	9 complaints or 0.8	per sprayer,	6 kinds of symptoms
6# to 10 yrs.	8	26 complaints or 3.25	per sprayer,	11kinds of symptoms
12 yrs.	1	3 complaints or 3.0	per sprayer,	3 kinds of symptoms
Vitreous Enamel Penna.	76	94 complaints or 1.2	per sprayer,	16 kinds of symptoms
N.S.C. sheet	26	79 complaints or 3.0	per sprayer,	22 (19 females)
castings	35	91 complaints or 2.6	per sprayer,	28 (19 females)

TABLE F

Control Blood Studies—Acute Accident Cases from St. Joseph's Hospital, Detroit, 1925

	Red Blood Cells	White Blood Cells
	3 980 000	7 400
	3 982 000	7 800
	3 986 000	7 850
	4 040 000	8 350
	4 065 000	8 500
	4 146 000	8 600
	4 182 000	8 750
	4 263 000	8 750
	4 428 000	8 800
	4 492 000	8 950
	4 498 000	8 890
	4 510 000	9 000
	4 522 000	9 100
	4 522 000	9 100
	4 523 000	9 100
	4 524 000	9 150
	4 546 000	9 200
	4 683 000	9 300
	4 691 000	9 300
	4 695 000	9 400
	4 696 000	9 400
	4 698 000	9 400
	4 742 000	9 450
	4 743 000	9 500
	4 744 000	9 500
	4 744 000	9 650
	4 744 000	9 700
	4 816 000	9 750
	4 816 000	9 800
	4 819 000	9 800
	4 916 000	9 850
	5 016 000	9 850
	5 019 000	9 900
	5 126 000	10 000
	5 246 000	10 050
		10 100
	160 163 000	10 050
Average	4 576 000	10 200
		10 300
		10 350
		10 350
		10 400
		10 450
		10 500
		10 550
		10 750
		10 750
		10 750
		11 250
		11 250
		11 350
		11 650
		12 150
		12 350
		12 700
		8 950
		10 750
		558 750
Average		9 806

TABLE G

Lacquer Sprayers; White Cell Counts by Length of Service

Length of Service	Number Sprayers	Total W. B. C. 4000 to 4999	5000 to 5999	6000 to 6999	7000 to	Polymorphs. 1000 to 1999	2000 to 2999	3000 to 3999	4000 to 4999
Up to 2 mo........	6			1 (16%)					1 (16%)
2# to 4 mo.........	10			4 (40%)	1 (10%)			2 (20%)	4 (40%)
4# to 6 mo.........	15		3 (20%)	1 (6%)	2 (13%)		2 (13%)	3 (20%)	5 (33%)
6# to 12 mo........	34	1 (3%)	6 (17%)	7 (20%)	4 (11%)		4 (11%)	12 (35%)	9 (26%)
1# to 2 yrs........	29		4 (14%)	7 (24%)	3 (10%)			10 (34%)	7 (24%)
2# to 4 yrs.........	50	3 (6%)	4 (8%)	14 (28%)	10 (18%)	1 (2%)	2 (4%)	13 (26%)	21 (42%)
4# to 6 yrs........	9	2 (22%)	2 (22%)		2 (22%)		2 (22%)	2 (22%)	1 (22%)
Over 6 yrs.........	7		1 (14%)	1 (14%)	3 (43%)	1 (14%)		2 (28%)	3 (43%)
Totals............	160	6 (4%)	20 (12%)	35 (22%)	25 (15%)	2 (1%)	10 (6%)	44 (27%)	51 (32%)
Percentage below certain levels Below		5000	6000	7000	8000	2000	3000	4000	5000
Up to 2 mo........				16%	16%				16%
2# to 4 mo.........				50%	60%			20%	60%
4# to 6 mo........			20%	26%	39%		13%	33%	66%
6# to 12 mo.......		3%	20%	27%	38%		11%	46%	72%
1# to 2 yrs........		3%	17%	41%	51%			34%	70%
2# to 4 yrs........		6%	14%	48%	66%	2%	6%	32%	74%
4# to 6 yrs........		22%	44%	44%	66%		22%	44%	55%
Over 6 yrs.........			14%	28%	71%	14%		42%	85%

TABLE H

Percentage Distribution of Blood Cell Counts by Length of Service

N. S. C. Lacquer Mil. r. b. c.	to 2 mo.		to 4 mo.		to 6 mo.		to 12 mo.		to 2 yrs.		to 4 yrs.		to 6 yrs.		6 yrs.	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
5.5 to 5.9	.	..	.	..	.	..	.	..	1	3	.	..	1	10	.	..
5.0 to 5.4	1	17	2	20	2	13	5	15	3	10	6	12	2	20	.	..
4.5 to 4.9	3	49	2	20	5	34	13	38	15	52	18	34	5	50	2	29
4.0 to 4.4	1	17	4	40	5	34	14	41	8	28	20	38	1	10	4	57
3.5 to 3.9	1	17	2	20	2	13	2	6	2	7	8	16	1	10	1	14
3.0 to 3.4	.	..	.	..	1	6	.	..	.	..	.	..	.	..	.	..
W. B. C.																
12000 plus	.	..	.	..	1	6.5	1	3	.	..	.	..	.	..	.	..
11000 plus	1	17	.	..	1	6.5	.	..	2	7	1	2	.	..	.	..
10000 plus	4	66	1	10	1	6.5	1	3	5	17	4	8	.	..	1	14
9000 plus	.	..	3	30	3	20	5	15	3	10	7	14	1	12	.	..
8000 plus	.	..	.	..	3	20	9	26	5	18	7	14	2	22	1	14
7000 plus	.	..	1	10	2	14	4	13	3	10	10	20	2	22	3	44
6000 plus	1	17	5	50	1	6.5	7	20	7	24	14	28	.	..	1	14
5000 plus	.	..	.	..	3	20	6	18	4	14	4	8	2	22	1	14
4000 plus	.	..	.	..	.	..	1	3	.	..	3	6	2	22	.	..
Polymorphs.																
9000 plus	.	..	.	..	1	7	1	3	.	..	.	..	.	..	.	..
8000 plus	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..
7000 plus	.	..	.	..	1	7	.	..	1	3	2	4	.	..	.	..
6000 plus	3	50	4	40	1	7	3	10	6	21	6	11	1	11	.	..
5000 plus	2	33	.	..	3	20	5	14	5	17	4	7	3	34	1	14
4000 plus	1	17	4	40	5	32	9	26	7	24	21	39	1	11	3	43
3000 plus	.	..	2	20	3	20	12	35	10	35	13	31	2	22	2	29
2000 plus	.	..	.	..	1	7	4	12	.	..	3	6	2	22	.	..
1000 plus	.	..	.	..	.	..	.	..	.	..	1	2	.	..	1	14
Lymphs.																
6000 plus	.	..	.	..	.	..	.	..	.	..	1	2	.	..	.	..
5000 plus	1	17	.	..	.	..	1	3	1	3	1	2	.	..	1	14
4000 plus	1	17	.	..	1	6	2	6	2	7	3	6	.	..	.	..
3000 plus	3	49	3	30	7	47	9	26	8	28	6	12	1	12	3	43
2000 plus	.	..	4	40	7	47	17	50	13	45	31	62	4	44	3	43
1000 plus	1	17	3	30	.	..	5	15	5	17	8	16	4	44	.	..

TABLE I
Air Tests for Lead

Test No.	Lead in Air Mg. per Liter	Volume Sample taken Liters	Mg. Lead Found	% Lead in Material	Air Vel. Ft. per Minute	Relative Humidity	Spray Gun Air Pressure	Plant No.	Physical Exam. No.
21	.0	9	.0	3	61	51	85	2	46
23	.001	9	.006		140	61	85	2	49
25	.0	9	.0	15	49	51	85	2	50
26	.0	9	.0	15	49	51	85	2	50 (interior)
29	.0	7.5	.0	.002	0	52	90	3	
30	.0	9.2	.0	.002	0	52	90	3	
31	.0	9	.0	15	49	52	95	4	86
32	.0	9	.0	15	49	52	95	4	86
33	.096	9	.870	24	64	65	100	4	86
47	.490	4.4	2.160	11	65	74	105	5	
48	.001	5.05	.003	9	46	65		5	
49	.001	4.7	.006	9	46	65		5	
54	.0	4.7	.0	0	160	44	105	6	
55	.0	5.25	.0	0	160	44	105	6	
58	.0	5.05	.0	12	good	dry	105	6	206
61	.001	4.45	.004	12	good	wet	105	6	206
84	.0	12	.0	.5	0	65	50	12	205 253 (interior) 254
85	.001	12	.010	19	300	67	90	11	250 (exterior)
86	.001	12	.009	19	300	67	90	11	250
87	.0	2.25	.0	(.01 .8)	43	54	85	17	257
88	.007	9	.060	(6.3)	41	54	85	17	256
89	.0	9	.0	19.2		33	85	17	260
90	.600	9	5.4	19.2	40	33	85	17	261
91	.0	9	.0	8	8	33	95	17	258
92	.100	9	.88	8	8	33	95	17	259
93	.040	9	.360	29		30	95	17	
94	.045	9	.403	29		30	95	17	

TABLE J
Analysis of Material Samples

Sample No.	% of Silica Found in Dried Sample	Class of Material	Maker	Description	Plant No.	Air Test Max. Mg. Lead per liter	% Lead in Material as Sprayed
1	....	Glaze	1	....	2	.000	3
2	....	Primer	1	First coat	2	.000	15
3	....	Paint	2	Staywhite	3	.000	.00
4	....	Primer	3	Oxide, 1st coat	4	.000	15
5	....	Surfacer	3	....	4	.096	24
6	....	Primer	3	....	5	.490	11
7	....	Surfacer	3	....	5	.001	9
8	....	Primer	1	Oil solvents	6	.000	12
9	....	Surfacer	1	Lacquer solv.	6	.000	.000
10	....	Lacquer	4	....	6	....	.190
11	....	Lacquer	4	....	6	....	.130
12	42.8	Vitr. En.	5	for sheet m.	7	....	.700 sol 2.800 tot.
13	21.2	Vitr. En.	5	for cast		....	.400 sol. 26 tot.
14	44.8	Vitr. En.		for sheet m.	8	....	.000 sol.
15	25.8	Vitr. En.	5	for cast	8	....	20 sol. 23 tot.
16	....	Paint	6	Asepticote	12	.000	.5000
17	....	Paint	7	Lead in oil	11	.001	19
18	....	Primer	8	Red Lacq.	17	.007	.010
19	....	Glaze	8	Purple sol-	17	.007	.800
20	....	Guide	8	Yellow vents	17	.007	6.300
21	....	Surfacer	9	....	17	.600	19
22	....	Primer	9	Red Oxide	17	.100	8
23	....	Primer	9	2d coat	17	.045	29
24	47.1	Vitr. En.	10	for sheet	9	....	.0
25	24.5	Vitr. En.	10	for cast	9	....	14 sol. 15 tot.
26	37.2	Vitr. En.	11	for cast	19	....	3.8 sol. 3.8 tot.
27	....	Paint	....	French Grey	26	....	.070
28	42.1	Vitr. En.	12	for sheet	28	....	.0
29	43.6	Vitr. En.	12	for sheet	28	....	.0
30	24	Vitr. En.	11	for cast	28	....	11 sol. 13 tot.

TABLE K

Lead in Feces Samples

Milligrams per gram of sample; grouped to correspond with the findings of the U. S. P. H. Service Committee investigation of the Health Hazard from Tetraethyl Lead Gasoline as given in Table No. 41 of their report.

Under .0001		.0001–.003		.003–.010		.0101–.030		.0301–.100		.1001–.300	
Physical No.	Material Sprayed	Physical No.	Material Sprayed	Physical No	Material Sprayed	Physical No.	Material Sprayed	Physical No.	Material Sprayed	Physical No.	Material Sprayed
50	U	44	Pr.	179	Pr.	76	U	56	U	245	VEC
75	Gl.	45	Pr.	282	Pr.	130	Sl	250	P		
81	Pr.	47	U			180	Pr.	257	Pr.		
85	Pr.	51	U			289	U	258	Pr.		
126	Sl	53	L			294	Ru	261	Gl		
135	Ox	55	U			308	VEC	263	U		
182	U	77	Gl			310	VEC	283	U		
183	U	78	Gl			313	VEC	290	U		
185	U	79	U								
186	U	80	U								
187	U	82	Pr.								
227	VEC	83	U								
256	U	84	U								
259	Pr.	86	U								
262	U	124	Sl								
329	P	184	U								
		188	U								
		226	VEC								
		251	P								
		312	VEC								
Total	16		20		2		28		8		1
%	29		36		3		15		15		2
Group E, U. S. P. H. 43 cases with definite lead exposure			5	2			2		32		2

226 had 909 stipple cells per 100,000 r. b c.
227 had 400 stipple cells per 100,000 r. b

TABLE L

Summary of Analysis for Lead in Feces

	Under .0001 mg. per gram	.0001 to .003 mg. per gram	.0031 to .010 mg. per gram	.0101 to .030 mg. per gram	.0301 to .100 mg. per gram	.1001 to .300 mg. per gram
AUTO MEG.						
Plant 4	3	8	0	1	0	0
Plant 5	5	1	0	1	0	0
Plant 6	4	2	1	1	0	0
Plant 2	1	7	0	0	2	0
Plant 17	2	0	1	0	5	0
Plant 18	0	0	0	2	1	0
PAINTERS	1	0	0	0	1	0
VITREOUS ENAMELERS						
Plant 7	1	0	0	0	0	0
Plant 8	0	2	.	.	.	.
Plant 9	0	0	0	0	0	1
Plant 19	0	1	0	3	0	0

No samples taken in Plant 1.

TABLE M

Change in Lead with Gun Pressure

Lead tests by gun pressure

Pressure	105	11% lead in material	.490 lead per L.
Pressure	105	9% lead in material	.001 lead per L.
Pressure	100	29% lead in material	.040 lead per L.
Pressure	100	....	.045 lead per L.
Pressure	100	24% lead in material	.096 lead per L.
Pressure	95	19.2% lead in material	.600 air vel. 4(
Pressure	95	8% lead in material	.100 air vel.
Pressure	95	....	.000 air vel.
Pressure	90	19% lead in material	.001 air vel. 300
Pressure	90	....	.001 air vel. 300
Pressure	85	.01, .8, .6, .3% at same booth	.007 air vel.
Pressure	85	....	.0 air vel.
Pressure	85	25% lead in material	.001 air vel.
Pressure	85	19.2% lead in material	.0 air vel. under 8
Pressure	85	15% lead in material	.0 air vel.
Pressure	85	3% lead in material	.0 air vel.

TABLE N

Impinger Tests in Vitreous Enamel Plants

Plant Number	Test Number	¼ unit sized enamel particles per cubic foot of air sampled	Air velocity in feet per minute at sampling point	Relative humidity	Air pressure at spray gun	Area of work in square inches	Cast iron or sheet metal	% of time man is spraying	Lbs. of enamel sprayed per day	Physical examination number	% total lead in enamel sprayed	% soluble lead in enamel sprayed	% combined and free silica as SiO_2	
7	70	24,000,000	36	60	85	200	s	95	1000	....	2.8	0.7	42.8	automatic booth
7	71	27,000,000	36	60	85	200	s	95	1000	....	2.8	0.7	42.8	automatic booth
7	72	13,000,000	30	76	85	12	s	50	500	220	2.8	0.7	42.8	incr. shadows R
7	73	23,000,000	130	76	85	50	c	50	500	218	26.0	0.4	21.2	incr. shadows R
7	74	25,000,000	130	76	85	50	c	50	500	218	26.0	0.4	21.2	
7	75	9,000,000	142	84	85	200	s	95	1000	....	2.8	0.7	42.8	automatic
8	76	4,900,000	136	76	100	10	c	30	200	228	23.0	20.0	25.8	
8	77	5,600,000	111	76	100	50	c	45	200	226	23.0	20.0	25.8	
8	78	20,000,000	240	76	100	180	s	80	400	229	0	0	44.8	
8	79	19,000,000	120	61	100	100	s	50	400	231	0	0	44.8	
8	80	11,000,000	120	61	100	60	s	50	400	231	0	0	44.8	
8	81	6,600,000	98	61	100	180	s	60	400	233	0	0	44.8	
8	82	3,700,000	98	61	100	180	s	60	400	233	0	0	44.8	
8	83	4,200,000	74	61	100	144	s	50	400	237	0	0	44.8	
9	95	1,800,000,000	negligi-	....	100	300	s	80	500	....	0	0	47.1	
9	96	350,000,000	ble	....	100	300	s	80	500	....	0	0	47.1	
9	97	170,000,000	"	....	100	300	s	80	500	240	0	0	47.1	
9	98	100,000,000	"	....	100	300	s	80	500	240	0	0	47.1	
9	99	140,000,000	"	....	100	300	s	80	500	244	0	0	47.1	incr. shadows R
9	100	110,000,000	"	....	100	300	s	80	500	244	0	0	47.1	r
19	201	540,000	257	....	65	100	c	90	400	....	3.8	3.8	37.2	
19	202	310,000	213	....	65	200	c	90	400	....	3.8	3.8	37.2	
19	203	340,000	166	....	65	100	c	90	400	....	3.8	3.8	37.2	
28	204	30,000,000	....	....	100	300	s	80	300	....	0	0	42.6	
28	205	34,000,000	....	....	100	100	s	70	300	....	0	0	42.6	
28	206	27,000,000	....	....	100	300	s	80	300	....	0	0	42.6	
28	207	2,200,000	....	....	100	400	s	60	200	....	13.0	11.0	24.0	
28	208	2,000,000	....	....	100	400	s	60	200	....	13.0	11.0	24.0	
29	209	740,000	97	....	100	300	c	60	400	....	....	....	....	
29	210	1,200,000	109	....	100	300	c	60	400	....	....	....	....	
29	211	1,100,000	128	....	100	50	c	40	200	....	....	....	....	
29	212	1,600,000	128	....	100	50	c	40	200	....	....	....	....	
29	213	1,500,000	....	....	100	100	c	60	400	....	....	....	....	

TABLE O

X-Ray Examinations

Plant No.	Physical No.	Material	Av. Impinger Count	Yrs. Spray.	Age	Sex	Diagnosis
7	218	VEC	24,000,000	1.06	26	M	P. – R. root & peribronch. infiltration
7	220	VES	17,750,000	4	24	M	P. – R. peribronch. infilt. rt. apical pleurisy
7	221	VES	17,750,000	5	22	M	P. – R. root & peribronch. infiltration
	239	VESC	445,000,000	9	25	F	P. – 2d stage silicosis R. diffuse miliary peribronch. infiltr.
9	241	VES	445,000,000	1	23	F	P. – R. root & peribronch. infiltration
9	245	VEC	445,000,000	1.03	24	M	P. – R. root & peribronch. infiltration
9	246	VESC	445,000,000	1.06		M	P. – R. peribronch. infiltration
19	308	VEC	397,000	2	29	M	P. – R. scattered tuberc. foci.
19	309	VEC	397,000	2	50	M	P. – M. –
19	310	VEC	397,000	1.03	26	M	P. – M. –
19	311	VEC	397,000	2	27	M	P. tuberc. rt. apex M. peribron. thicken.
19	312	VEC	397,000	2.06	23	M	P. – M. –
19	313	VEC	397,000	2	26	M	P. tuberc. lft. apex M. peribron. thicken.
19	314	VEC	397,000	2.06	22	M	P. – M. –
19	315	VEC	397,000	2.06	36	M	P. suspicious, possibly beginning silicosis M. peribron. thick. possibly chron. bron.
19	316	VEC	397,000	2	33	M	P. – M. –
19	317	VEC	397,000	1.06	23	M	P. – M. –
19	318	VEC	397,000	3	29	M	P. – tuber. rt. apex M. tuber. healed
19	319	VEC	397,000	1.06		M	P. – M. –
19	320	VEC	397,000	1.06		M	P. – M. –
19	321	VEC	397,000	1.06		M	P. – M. –
28	339	VEC	2,100,000	1	19	M	P. –
28	340	VEC	2,100,000	1	21	M	P. –
28	341	VES	30,300,000	4.06	35	F	P. –
28	342	VEC	2,100,000	4	40	F	P. prob. neg. (breath)
28	343	VES	30,300,000	3	22	F	P. –
28	344	VES	30,300,000	3.06	42	F	P. –
28	345	VES	30,300,000	5	24	F	P. – 1st or prob. 2d stage silicosis
28	346	VES	30,300,000	1.05	18	F	P. –
28	347	VES	30,300,000	5	28	M	P. – (foreman)
28	348	VEC	2,100,000	7	45	M	P. – (foreman)
29	354	VEC	1,228,000	3.06	42	M	P. – possible 1st stage silicosis

P.—Dr. Pancoast. R.—Dr. Reynolds. M.—Dr. Murphy.
– negative silicosis diagnosis.

TABLE P

Summary of X-Ray Diagnoses Made by Dr. Pancoast

Penna. Survey			
52 readable negatives	negative	28 or 54%	
	suspicious	13 or 25%	
	tuberculosis	3	
	pleurisy	1	
	silicosis	7 or 13.46%	
	age possible a factor 2 or		4% of total 29% positives
	previous occupation a factor 2 or		4% of total 29% positives
	combined positive & suspicious		20
	other factors contrib.		4
N.S.C. Survey			
33 negatives; 32 readable	negative	24 or 75%	
	suspicious	1 or 30%	
	tuberculosis	4	
	silicosis	3 or 9.37%	
Total—Both Surveys			
84 readable negatives	negative	52 or 62%	
	suspicious	14 or 16.6%	
	positive	10 or 11.9%	
	No secondary factor	6 or 7.1%	

By Length of Service and Materials Sprayed.

		Sheet	Cast.	
Penna.	to 1 yr.	2	6	all negative
	from 1 yr. to 2 yrs.	2	..	negative
	from 1 yr. to 2 yrs.	..	2	tubercular foci
	from 1 yr. to 2 yrs.	..	1	pleurisy
	from 1 yr. to 2 yrs.	3	1	suspicious
	from 1 yr. to 2 yrs.	2	1	silicosis
	from 2 yrs. to 4 yrs.	5	8	negative
	from 2 yrs. to 4 yrs.	2	2	suspicious
	from 2 yrs. to 4 yrs.	3	..	silicosis
	from 4 yrs. to 5 yrs.	..	1	negative
	from 4 yrs. to 5 yrs.	1	..	silicosis
	over 5 yrs.	..	1	negative
	over 5 yrs.	1	1	silicosis
	time unknown	1	2	negative
	time unknown	1	..	tubercular 2ci
	time unknown	..	3	suspicious
		23	29	
	10 or 43.5%		18 or 52%	negative
	5 or 21.75%		6 or 30%	suspicious
	7 or 30.5%		1 or 3.4%	silicosis.

By Length of Service and Materials Sprayed

		Sheet	Cast.	
N.S.C.	to 1 yr.	1	2	all negative
	from 1 to 2 yrs.	1	11	negative
	from 1 to 2 yrs.	..	2	tubercular foci
	from 2 to 4 yrs.	1	..	moved—uncertain
	from 2 to 4 yrs.	2	3	negative
	from 2 to 4 yrs.	..	1	suspicious
	from 2 to 4 yrs.	..	1	silicosis—first stage
	from 2 to 4 yrs.	..	2	tubercular foci
	from 4 to 5 yrs.	3	..	negative
	from 4 to 5 yrs.	1	..	silicosis—1st or 2d stage
	over 5 years	..	1	negative
	over 5 yrs.	1	..	silicosis—second stage
		10	23	
	7 or 70%		17 or 74%	negative
			1 or 4%	suspicious
	2 or 20%		1 or 4%	silicosis

Summary of both studies		
Negative findings		
to 1 yr.	3	8
from 1 to 2 yrs.	3	11
from 2 to 4 yrs.	7	11
from 4 to 5 yrs.	3	1
over 5 years	..	2
time unknown	1	2
	17 or 53%	35 or 67%
Suspicious findings		
from 1 to 2 yrs.	3	1
from 2 to 4 yrs.	2	3
from 4 to 5 yrs.	..	..
over 5 years	1	1
time unknown	..	3
	6 or 19%	8 or 15%
Silicosis		
from 1 to 2 yrs.	2	1
from 2 to 4 yrs.	3	1
from 4 to 5 yrs.	2	..
over five years	1	..
	8 or 25%	2 or 4%
Tubercular foci		
from 1 to 2 yrs.	..	4
from 2 to 4 yrs.	..	2
time unknown	1	..
Pleurisy—2 yrs.	..	1
Grand Totals	32	52

A number not reported as positive or suspicious by Dr. Pancoast showed more or less increased density of root shadows and thickening of peri-bronchial shadows extending in one or more lobes and were called positive or suspicious by the men taking the films.

APPENDIX II

Efficiencies of Respirators Filtering Lead Paint, Benzol, and Vitreous Enamel Sprays*

By S. H. Katz, E. G. Meiter and F. H. Gibson,
U. S. Bureau of Mines Experiment Station, Pittsburgh, Pa.

REASONS FOR INVESTIGATION

At the instance of, and with funds provided by the National Safety Council, the Bureau of Mines undertook an investigation of respirators to determine their efficiency in protecting painters and finishers operating spray guns, which spray paint onto the surface being coated. Some paint mist may fail to lodge upon the surface and the minute droplets of microscopic size may float in the air. The operator who is manipulating the gun is within arm length of the spray and may breathe some spray and vapors of paint solvent. When paints that contain lead-bearing or poisonous pigments are applied, it is best that the operator be protected from inhaling the mist. Some paint constituents, such as benzol or other thinners which are sometimes used, may evolve vapors detrimental to health.

Paint spraying is making inroads into the older method of applying paint. Many such operations in factories are performed in booths with strong air drafts to exhaust the mists and the vapors through vent pipes to the exterior of the buildings. Respirators are frequently worn by operators as additional protection.

In many spray-painting operations with the materials dealt with in this investigation, especially those not conducted under factory conditions, respirators and ventilation are the only protective means for the operator. Because of the important part respirators are assuming in this industry their efficacy was determined by laboratory tests.

The efficiencies of the respirators were similarly tested with sprays of silica dust in aqueous suspension because vitreous enamels, which include silica as an ingredient, are being applied to sanitary ware, enameled stoves and the like, by the spray process, preliminary to firing.

Problems Proposed

The specific questions proposed by the National Safety Council to be answered by this investigation were as follows:

1. What filtering material, if any, is adequate—
   (a) To reduce the lead content of the air to which a spray coater is exposed from 200 milligrams per cubic meter to 0.6 milligram per cubic meter?
   (b) To reduce the amount of benzol under similar conditions from 2,000 to 75 parts per million?
   (c) To reduce the number of silica particles under similar conditions from 200,000,000 to 100,000 per cubic meter as determined by the Palmer method?
2. How long would such a layer function?
3. How do certain typical masks now available measure up to this standard?

The concentrations stated above for lead and benzol should not be construed as those to which spray painters are commonly exposed. They represent more nearly the high concentrations which can quickly cause sickness and are to be considered as extremes.

Brief of Findings

It may be stated as a result of the tests that in general the respirators with cotton, paper or fabric filters remove 90 or more per cent of the lead from air carrying paint mist. These respirators restrain none of the solvent vapors. The addition of a canister or cartridge of activated charcoal to the respirator removes all solvent vapors until the charcoal becomes saturated. The useful life of filters is determined by their increase in resistance, which necessitates changing for fresh filters at intervals of several hours. When charcoal is saturated, the cartridge must be exchanged for a fresh one. Canisters of the size used with gas masks may last for weeks before a change is necessary.

The respirators were somewhat less efficient against the silica-dust sprays, but they restrained 24 per cent or more of the dust from the air passed through them; most were more than 50 per cent efficient.

Acknowledgment

This investigation was conducted under supervision of R. R. Sayers, chief surgeon, and A. C. Fieldner, chief chemist, of the Bureau of Mines, to whom the writers are indebted for guidance and counsel. The photomicrographs were taken by A. H. Emery, assistant geologist and petrographer of the Bureau.

DESCRIPTION OF RESPIRATORS TESTED

Twelve respirators representing the different industrial types were tested. It was impracticable to test every make of respirator, but the types included are representative and the results obtained indicate the results to be expected from the field of respirators as a whole. Of the respirators tested, nine were filters without absorbents for vapors, three had both filters and activated charcoal adsorbent for solvent vapors.

Number 1 is a respirator with a sponge filter. The face cushion is a rather firm but flexible rubber with the edge curved outward so that a surface of rubber, rather than an edge, is in contact with the face. The body is of sheet aluminum. A rubber flutter-valve underneath permits escape of exhaled air. The sponge is inclosed in the round box at the front, between wire screens. The front screen is removable so that the sponge may be taken out for cleaning or wetting.

Number 2 is a respirator similar to Number 1 except that the filter is a thick paper made of cotton fiber. Three filters averaged 1.02 mm. (0.040 inch) in thickness (measured between metal plates). A supply of circular filters 6.11 cm. in diameter (2-13/32 inches) accompanies each respirator for changing when resistance is increased by clogging. Filters of cotton felt are also provided with a respirator of this type. (In the tables that follow, the respirator with cotton felt filter is designated as No. 2A.)

Number 3 is a respirator with a thin paper filter. The papers are made of cotton fiber 0.2 mm. thick, and are supplied in circles of 8.25 cm. (3.25 inches) in diameter. The body is of rubber with a thin edge fashioned to lay the inner rubber surface of the respirator against the skin. A wire is attached over the bridge of the nose, which may be bent to shape the rubber body into the contour between nose bridge and cheeks. The paper is held in an adapter of sheet aluminum. This respirator has no exhale valve but the manufacturer provides the respirator with valves if desired.

Number 4 is another respirator with paper filter. The body is of aluminum. A pneumatic rubber cushion lays against the face. The exhale valve on the upper side is of the mica-disc type. The paper filter is held by an aluminum ring, brass wire screen, and a spring wire fastener. The filters are of gauzy tissue paper and four or more are used as a filter. Ten papers measured 1.2 mm. (0.05-inch) in thickness.

Number 5 is a respirator with a body of fly-screen shaped into a cone and cut at the basal edge to the contour of the face. The screen is covered with two layers of cotton flannel. The flannel is bound over the lower edge and lies against the face. By bending the wire screen it may be shaped to fit various facial contours. There are no valves; inhalations and exhalations pass through the filter.

Number 6 is a respirator with a body made of pyroxylin fabrikoid. This is cut away in the center and the filter of one layer of fine silk gauze and three layers of cheesecloth is sewed into the opening. At the position over the nose bridge a wire is bound onto the respirator for conforming to the facial contours.

Number 7 is a respirator of cotton wool quilted between cheesecloths. The fabric is gathered over the bridge of the nose to form a sort of nose pouch. About 5 grams of charcoal granules are spread through the cotton for the purpose of absorbing solvent vapors, but the amount is insufficient to be of value. The respirators are thrown away when soiled.

Number 8 is a respirator with small canister or cartridge containing 60 c.c. of granular activated charcoal with filters of gauzy

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paper tissue and wire screen supports at inlet and exit to the cartridge. Each of the two filters, one at inlet side, one at outlet side of cartridge, consists of 10 papers measuring 1.7 mm. (0.067-inch) in thickness measured between metal plates. The filter layer in the cartridge measures 6.35 cm. in diameter and 2.54 cm. thick (2.5 inches by 1 inch). The cartridge screws into the respirator body which is similar to that of Numbers 1 and 2, and seats against a rubber gasket. The weight with canister attached is 195 grams (6.9 ounces) somewhat heavier than the other respirators described above.

Number 9 is the Bureau of Mines respirator developed to present a large filtering surface with a correspondingly low resistance to breathing, and a high filtering efficiency[1]. These respirators have at present been made and used only in the laboratories of the Bureau of Mines. The filter is of canton flannel, either 2 or 3 plies, shaped into a turban for the head. The frame is of spring wire, and there is a lining of pyroxylin fabrikoid which is impervious to air and prevents dust being drawn into the wearer's hair. Between the lining and the filter is a separator about an inch thick made of sterilized, curled hair, such as is used by upholsterers; it permits passage of air, with negligible resistance, from all parts of the filter surface to the exit valve on top. The valve prevents back flow of exhaled air. A rubber tube leads the filtered air from the valve down between the eyes, to a nose cap of rubber; only the nose is covered, so the wearer can talk as usual or expectorate. A coiled spring in the rubber tube holds the nose cap against the face with a slight pressure and prevents leakage. At the lower side of the nose cap is an exit provided with a rubber flutter valve or check for eliminating exhaled air. This respirator weighs about 625 grams (22 ounces), but the weight is not oppressive to the wearer.

The Bureau of Mines respirator may be rid of accumulated dust by means of compressed air blown through a tube attachment. But the filter cannot be changed readily, so it would hardly be serviceable in paint mist. It should be good in vitreous enamel spray.

Number 10 is an army type gas mask used by a spray painter. Masks of this type are now used in numerous industries. The canister is carried in a haversack supported from the neck. It contains 600 c.c. of activated charcoal to serve as an absorbent for vapors. There are two filters of cotton wool between wire screens and one of Turkish toweling.

Number 11 is a Fogler flat felt filter and mask; a canister of charcoal is attached to the filter, or it may be used without the charcoal canister. The Fogler flat felt filter consists of two rectangular pieces of an especially dense woolen felt about 21.6 by 24.1 centimeters (8½ by 9½ inches) by 3 millimeters (one-eighth inch) thick, with a crimped wire screen separator of slightly smaller dimensions between. On the outside of the felts are two similar crimped screens, both of which are covered with canvas. The fabric and felt edges are all thoroughly rubberized and vulcanized together. Each canvas side is perforated by five holes 1 centimeter (0.39 inch) in diameter. A tube about 2.54 centimeters (1 inch) in diameter passes through one canvas and one felt and connects with the central space between the felts. The air, filtering, passes through the canvas or its perforations, filters through the felt to the central space, passes through the exit tube to the canister containing activated charcoal and then to the mask for breathing. If protection from dust only is required, the canister is omitted. The large filtering area of the Fogler flat felt filter permits breathing through the highly efficient filter without excessive resistance to air flow or rapid clogging. It is the most efficient of the types so far employed in industry for retaining the very finest suspensoids. A disadvantage is that the filter cannot be cleaned of paint that may lodge on the felt and the filters are rather expensive for only a short period of use. Dusts may be blown out with air under pressure.

Number 12 is a respirator similar to Number 3, but with a small rubber hose connection to the compressed air line of the spray gun. The amount of air delivered to the respirator is regulated by a needle valve. At the respirator the air enters the metal cup which encloses a filter of cotton fiber paper. The paper retains oil droplets, or dirt. Two flat rubber check valves, one on each side, are mounted on the rubber body; they provide exits for the air stream. The valves are retained and protected by metal caps, they are replaceable and a supply accompanies each respirator for changing when they no longer function properly, due to paint or deterioration. When an air stream of about 2 cubic feet a minute passes through this respirator, it can exclude all paint and vapors of solvents. The air supply must, of course, be free of distasteful oil vapors from the compressor or air line.

Figure 5 shows a hose mask or helmet (Number 13) especially for spray painters. The outer covering is a cotton twill which may be separated from the light metal frame, for washing. A hose conducts compressed air to the helmet and the air discharged downward over the inside of the eye-pieces to prevent fogging. A woolen headpiece supports the weight upon the head. Two cubic feet or more of free air per minute is fed into the helmet; the air may be supplied by the compressor for the spray gun. When sufficient air discharges into the helmet the spray gun operator is completely protected from inhaling mist or vapors. No tests were made with the helmet because it does not filter the air, nor with the respirator shown in Figure 4.

TESTS OF RESPIRATORS IN PAINT MIST

Apparatus for Testing Filtering Efficiencies.

The apparatus used to test respirators against paint mist is shown diagrammatically in Figure 6. The mechanical equipment, including air compressor, air receiver, air cleaner, pressure regulator and spray gun, was of standard make. The compressor was rated at 150 pounds working pressure but when the spray gun was operated the pressure regularly obtained at the trigger of the gun was 20 to 30 pounds. This gave a good spray and was ample for the purpose. The gun was supported in a box 30 inches on a side, open on one side which was draped with a cloth curtain. The gun discharged against a sheet-metal plate 9 inches from the nozzle. Paint drippings were caught in a pan. The trigger of the gun was fixed to spray uniformly by means of a metal loop and thumb-screw to depress the trigger. The density of the spray was kept as uniform as possible by adjustments occasionally according to its appearance.

The respirator undergoing test was shielded by baffles from direct approach of spray from the gun. It was mounted in a holder by means of plastecene (modeling clay); the respirator valves were sealed so that all the air passed through the filter, and filtering efficiencies as determined were unaffected by any possible leakage of unfiltered air. The respirator was placed downward on a support so that no paint particles lodged upon it by gravity. Air was drawn through the respirator at the rate of 32 liters (1.13 cubic feet) a minute, the rate of breathing of a man doing vigorous work.

The filtered air passed from the respirator directly into an electric precipitator tube of glass, lined with analytical filter paper. The tube was 2.5 cm. (1 inch) in diameter and 30 c.m (12 inches) between inlet and outlet. Operation without the paper (used to catch precipitated paint) showed complete precipitation of paint in the first half length of precipitator tube. The inner electrode was a platinum wire; the outer was copper foil bound around the glass tube; a pressure of 15,000 volts from a transformer was employed.

From the precipitator the air passed to a solution of potassium iodide and sodium thiosulfate to remove ozone and oxides of nitrogen, then through a flow-meter to measure the flow rate and to the suction pump.

Tests were run 15 to 60 minutes in order to obtain sufficient lead for chemical determination. After each test the filter paper with its lead was removed from the precipitator; the inner electrode and glass surfaces of the precipitator were thoroughly cleaned and the cleanings put with the filter paper. The filter on the respirator was removed (the respirator was destroyed when necessary), the lead caught thereon and lead caught by the Cottrell precipitator were determined separately by chemical analysis according to the method described later.

The efficiencies of the respirators were calculated from the results obtained thus:

$$\frac{\text{Weight of lead caught by respirator} \times 100}{\text{Weight of ld. caught by both respirator and precipitator}} = \text{percent efficiency.}$$

An effort was made to maintain the concentration of lead in the air before filtering about 200 milligrams per cubic meter as specified by the National Safety Council; but this was not readily attained and considerable variations occurred. However, previous work has shown that the concentration of the suspensoid in air exerts little or no effect on the efficiencies of the filters[2].

[1] Katz, S. H., Smith, G. W., and Meiter, E. G., Dust Respirators; Their Construction and Filtering Efficiency. Bureau of Mines Technical Paper 395, 1926, 52 pages.
[2] See reference 1.

Composition of the Paint.

The paint used was of the same composition throughout as follows: White lead (paste), 100 grams; linseed oil, 50 c.c.; and benzol, 25 c.c.

The paste white lead was 91 per cent white lead and 9 per cent linseed oil by weight.

The white lead and benzol were included in the paint because the questions proposed by the National Safety Council for this investigation included white lead and benzol. Other paint materials were excluded because they might increase the difficulties and extend the time and labor of determining lead and benzol.

in the table to correspond with the picture numbers as assigned.

Filtering efficiencies range from 74 per cent for respirator No. 6 with filter of silk gauze and 3-ply cheesecloth to 99.7 per cent for the No. 8 cartridge with 2 filters each of 10-ply gauze tissue paper. The sponge respirator No. 1 was 84 per cent efficient. All the others ranged above 94 per cent efficiency. The efficient respirators thus restrain nearly all of the lead in paint mist from air filtered through them.

These tests do not take into consideration possible leakage of unfiltered air due to poor fit upon the face, leaky valves or other leaks. On the other hand, greater weights of lead (but not greater percentages) were caught on the respirator filters under the test conditions, than may be expected in similar circumstances in practice, because the volume of air filtered (32 liters per minute which is an excessive breathing rate) is greater than the volume inspired under ordinary painting practice. In respirators fitted with care by shaping to the facial contour of the wearer and careful adjustment this leakage may possibly be eliminated. Leakage at valves or other places may sometimes occur. Care should be taken that valves are in good condition and function well. As leakage can annul the benefits of an otherwise good respirator, it is important that the wearer be careful to eliminate all leaks.

TABLE 1

Efficiencies of Respirators Filtering Lead in Paint Mist from Spray Gun. Rate of Air Flow, 32 Liters a Minute. Time of Testing, 31¼ Minutes, Giving 1 Cu. Meter of Filtered Air

Test No.	Number of respirator	Filter material	Resistance to air flow at 85 liters per minute, inches of water		Aver. amount of lead in air, mg. per cu. meter	Filtering efficiency of respirator, per cent	Remarks
			Start	End			
807	1	Sponge	0.3	0.3	395	84	Sponge was wet before test
809	2	Cotton paper	1.0	2.5	558	98.7	1 ply paper in filter
818	2	Cotton paper	1.0	1.6	397	97.3	1 ply paper in filter
819	2	Cotton paper	1.1	2.0	417	98.3	1 ply paper in filter
808	3	Cotton paper	0.15	0.5	359	96	1 ply paper in filter
816	3	Cotton paper	0.2	0.6	374	96	1 ply paper in filter
817	3	Cotton paper	0.5	0.9	353	98.3	2 plies paper in filter
814	4	Gauzy tissue paper	0.5	0.8	498	92	4 plies paper in filter
815	5	Cotton flannel	0.2	0.4	458	95	2 plies cotton flannel in filter
811	6	Silk gauze and cheesecloth	0.05	....	450	74	1 ply silk, 3 plies cheesecloth
812	7	Cotton wool	0.2	0.2	351	94	Cotton between cheesecloth, 109 sq. cm. of filter was exposed
810	2A	Cotton felt	0.7	1.7	551	97.9	Respirator body like that of No. 2.
820	2A	Cotton felt	0.6	1.2	417	97.5	Respirator body like that of No. 2.
821	2A	Cotton felt	0.7	1.2	394	97.7	Respirator body like that of No. 2.
813	8	Gauzy tissue paper	3.5	4.4	524	99.7	Cartridge with charcoal and 2 filters each of 10 plies
847	10	Cotton wool	3.6	3.9	76.1	99.7	The army type gas mask, canister contains 2 cotton filters, 1 of toweling and 600 c.c. charcoal
848	10	Cotton wool	3.6	3.9	71.3	98.8	The army type gas mask, canister contains 2 cotton filters, 1 of toweling and 600 c.c. charcoal
850	10	Cotton wool	3.4	3.6	75.3	99.6	The army type gas mask, canister contains 2 cotton filters, 1 of toweling and 600 c.c. charcoal
851	10	Cotton wool	3.4	3.5	59.6	99.3	The army type gas mask, canister contains 2 cotton filters, 1 of toweling and 600 c.c. charcoal
852	10	Cotton wool	3.6	3.8	65.7	99.7	The army type gas mask, canister contains 2 cotton filters, 1 of toweling and 600 c.c. charcoal

Determination of Lead.

The lead caught on filters and in precipitators was determined by methods described by the U. S. Public Health Service[3]. Briefly, the method is as follows:

Filters, papers or cellulosic substances bearing the lead are ashed in a muffle furnace at 550° ± 20° C., then dissolved in 1:1 hydrochloric acid solution, filtered and washed. Neutralize with sodium hydroxide, acidify with dilute acetic acid till color of thymol blue indicator changes, then add slight excess. Heat to boiling and precipitate lead as chromate with potassium chromate solution, adding slight excess. Keep hot for one hour, then digest over night. Filter off lead chromate, wash with hot water. Then transfer precipitate to beaker or flask with water and finally by treating filter with 1:2 hydrochloric acid, add potassium iodide and titrate with standardized sodium thiosulfate solution with starch indicator. Calculate data to metallic lead.

This simple method was sufficient when the lead was contaminated only by the small amounts of ash material from cotton or high grade filter papers. When considerable ash was present the lead was precipitated as sulfide, redissolved, and determined as before. Complete details are given in the reference cited.

FILTERING EFFICIENCIES OF RESPIRATORS IN PAINT MIST

Filtering Lead Paint Mist.

Table 1 lists the efficiencies of the respirators in restraining lead contained in the paint spray.; the respirators are numbered

Table 1 also gives the resistances of the respirators to a;r flowing at 85 liters a minute before and after the paint had lodged upon them. Most have less than 4 inches of water throughouti 4 inches is a maximum tolerable resistance[4]. Only one respirator, No. 8, with the cartridge filter, exceeded 4 inches; at the end of the test it showed 4.4 inches. Respirators tend to increase in efficiency as well as resistance with increase in deposited material on the filter, hence it is the increase in resistance rather than any filtering deficiencies developing with use that determine the useful life of a filter. Most of the filters had deposits of lead ranging from 351 to 558 milligrams developed in 31¼ minutes of testing (the gas mask canisters had 51 to 76 milligrams) without developing excessive resistance. As the consentrations of paint mist were higher than customarily encountered by spray painters, it appears that any of the filters can serve at least for a period of hours or a day before change is needed.

[3] Anon. Fairhall (chromate) method for minimal amounts of lead in fecal specimens: Ind. & Eng. Chem., vol. 18, April, 1926, pp. 431-432

[4] Schedule 14 A, Procedure for establishing a list of permissible gas masks: Bureau of Mines Aug. 25, 1923, 15 pp.

TABLE 2

Efficiencies of Various Fabrics Filtering Paint Mists. Filter Area, 100 Square Centimeters; Rate of Air Flow, 32 Liters per Minute

Test No.	Fabric	No. of plies	Period of testing minutes	Resistance to air flow at 85 liters per minute, inches of water Start	End	Average concentration of lead in air, mg. per cu. meter	Lead filtering efficiency, per cent	Average concentration of benzol in air, p.p.m.
822	Cheesecloth, 31 by 36 threads per inch, 42.0 g. per square yard	2	15	0.00	0.00	406	18	560
823	Cheesecloth, 31 by 36 threads per inch, 42.0 g. per square yard	3	15	0.00	0.00	504	23	600
824	Cheesecloth, 31 by 36 threads per inch, 42.0 g. per square yard	4	15	0.02	0.02	447	34	740
825	Cheesecloth, 31 by 36 threads per inch, 42.0 g. per square yard	5	20	0.02	0.02	432	39	550
781	Cheesecloth, 31 by 36 threads per inch, 42.0 g. per square yard	10	62½	0.02	0.02	253	51	550
826	Cheesecloth, 31 by 36 threads per inch, 42.0 g. per square yard	10	31¼	0.02	0.02	421	68	640
782	Cheesecloth, 31 by 36 threads per inch, 42.0 g. per square yard	20	62½	0.05	0.05	207	74	590
796	Muslin, 66 by 66 threads per inch, 130 g. per square yard	1	62½	0.2	0.6	328	67	780
797	Muslin, 66 by 66 threads per inch, 130 g. per square yard	2	62½	0.2	0.7	381	87	820
783	Muslin, 66 by 66 threads per inch, 130 g. per square yard	4	62½	0.6	1.6	181	95	610
798	Muslin, 66 by 66 threads per inch, 130 g. per square yard	6	62½	0.7	1.7	321	97.6	800
784	Muslin, 66 by 66 threads per inch, 130 g. per square yard	8	62½	1.1	2.1	228	98.7	770
804	Muslin, 66 by 66 threads per inch, 130 g. per square yard	12	31¼	1.7	2.8	346	99.2	1360
785	Muslin, 66 by 66 threads per inch, 130 g. per square yard	16	62½	2.2	3.3	218	99.4	960
794	Canton flannel, 44 by 76 threads per inch, 143 g. per square yard	1	62½	0.1	0.2	391	85	900
786	Canton flannel, 44 by 76 threads per inch, 143 g. per square yard	2	44	0.1	0.2	313	92	1120
795	Canton flannel, 44 by 76 threads per inch, 143 g. per square yard	3	62½	0.2	0.6	428	96	980
787	Canton flannel, 44 by 76 threads per inch, 143 g. per square yard	4	49½	0.4	0.5	194	97.9	1120
788	Canton flannel, 44 by 76 threads per inch, 143 g. per square yard	8	62½	0.9	1.0	154	99.2	530
803	Canton flannel, 44 by 76 threads per inch, 143 g. per square yard	8	31¼	0.9	1.0	540	99.5	1120
799	Cotton felt, 131 g. per square yard, thickness 0.84 mm.	1	62½	0.1	0.1	368	82	1010
800	Cotton felt, 131 g. per square yard, thickness 0.84 mm.	2	62½	0.1	0.1	249	91	960
801	Cotton felt, 131 g. per square yard, thickness 0.84 mm.	4	31¼	0.1	0.3	250	97.0	740
802	Cotton felt, 131 g. per square yard, thickness 0.84 mm.	6	31¼	0.4	0.4	334	98.5	1100
792	Filter paper, S & S No. 589, black label	1	42½	2.5	22.8	151	98.8	500
793	Filter paper, S & S No. 589, black label	2	53¾	4.9	41	181	99.6	690
806	Filter paper, S & S No. 589, black label	3	31¼	6.3	44	281	99.9	780
789	Absorbent cotton, between cheesecloths, 348 g. per square yard	1	62½	0.1	6.2	146	96.8	480
790	Absorbent cotton, between cheesecloths, 348 g. per square yard	2	62½	0.6	0.6	165	99.0	470
805	Absorbent cotton, between cheesecloths, 348 g. per square yard	3	31¼	1.0	1.0	451	99.5	1310
791	Absorbent cotton, between cheesecloths, 348 g. per square yard	4	62½	1.2	1.2	183	99.5	420

Against Benzol Vapors.

The filters of fabric or paper have no capacity whatever for restraining benzol vapors (or any similar vapors); activated charcoal adsorbent is needed for that purpose. Two of the respirators, No. 7 and No. 8 cartridge respirator, contained activated charcoal, also the canister of the army type gas mask, No. 10. These were tested against benzol vapor in air at a concentration of 2000 parts per million and air flow of 32 liters a minute, by methods used previously for testing canisters against gasoline vapors[5]. The respirator, No. 7, with about 5 grams of charcoal granules interspersed through the cotton showed no noticeable restraint of the benzol vapors at all, for the reason that the quantity of charcoal was insufficient and it was too irregularly dispersed. The No. 8 cartridge restrained the benzol for 19 minutes before a leakage of 75 parts per million of benzol appeared in the effluent air. An army canister, No. 10, containing 600 c.c. of high-grade activated charcoal lasted 250 minutes under similar conditions. In actual service the concentrations of solvent vapors are mostly much less than under the test conditions so that the useful life of adsorbents for vapors is many times longer; in fact, the writers have known canisters containing 600 c.c. of activated charcoal to last for weeks in daily service of spray painters.

FILTERING EFFICIENCIES OF FABRIC FILTERS

The filters in the various respirators cannot be very well compared for filtering qualities because of their different filter areas, part coverings, and different environments. Several filtering materials were therefore compared under uniform conditions by holding them in a special holder or flange in which exactly 100 square centimeters of filter area is exposed. Several plies of fabric or paper can be clamped together. They were backed, when necessary, by a screen to prevent bulging from air pressure. Table 2 gives the results of the tests, including the filtering efficiencies, duration of the tests, resistance to air flow (at 85 liters per minute) both before and after the paint was deposited on the filter, the average concentration of lead in the air and the average concentration of benzol in the air.

The filtering efficiencies are represented graphically in Figure 7. The amounts of lead passing through the filters (equal to 100 minus the percentage efficiency) are indicated as ordinates on a logarithmic scale and the number of plies of fabric in a filter are abscissa on a linear scale. The data points fall closely about their respective lines, drawn as smooth curves concave upward. The concavity indicates the effect of non-uniformity of size of particles of paint mist, as it has been found that particles of uniform size pass through multiple filters according to straight lines on the chart. This indicates that for particles of uniform size each filter effects removal of the same proportion of the suspensoids not removed by preceding filters[6]. In filtering the paint mist the first filter layer or layers remove then much more lead proportionately than succeeding layers, and the succeeding layers become less effective in restraining the paint because only the finer particles penetrate to them.

Table 2 also shows that concentrations of lead in the air before it was filtered ranged from a minimum average concentration of 146 milligrams per cubic meter to a maximum of 540 milligrams. That these differences in concentration had no considerable effect on the filtering efficiencies determined is indicated by the generally uniform trend of the data, regardless of the concentrations. Similarly, tests were conducted over periods of 15 to 62½ minutes without materially influencing the efficiencies found, judging by the regularity of the data.

The benzol content of the air ranged from a minimum of 420 p.p.m. (parts by volume per million parts of air considered as perfect gas) to a maximum of 1360 p.p.m. There is no general relation between the concentration of the benzol and the lead in air, owing to differences in operation of the spray gun and consequent precipitation or non-precipitation of lead on the painted surface, also to varying air currents in the box carrying the mist and vapor. The benzol determinations were made in the filtered air with an interferemeter calibrated against synthetic mixtures of benzol vapor and air.[5] The concentrations reported are averages of 4 to 20 separate observations during the course of a test which were not widely divergent. Errors for individual determinations were about 30 p.p.m. of benzol. Spray operators in less confined space than the box used for the experiments, which is usually the case in practice, would undoubtedly be exposed to less concentrated benzol vapors.

[5] Katz, S. H., and Bloomfield, J. J., Gas Masks for Gasoline and Petroleum Vapors: Tech. Paper 348, Bureau of Mines, 1924, 37 pp.

[6] See reference 1.

CHARACTERISTICS OF PAINT MIST

The efficacy of filters in restraining suspensoids in air is influenced greatly by the size and nature of the particles. To determine the character of the particles of paint mist floating in the air at the respirator filters, some were caught on cover glasses, such as are used with microscope slides, by rapidly moving the glasses in the mist under the filters undergoing test. The paint mist particles upon the glass were examined under a microscope. It is found that the droplets range from about 4 to 60 microns in diameter. Particles of pigment appear inside most of the droplets; the size of pigment particles range from about 1 to 4 microns. The oil about the pigment particles increases the particle size and aids the filters in retaining the lead. It is evident that the larger the droplets the more easily they are retained by a filter. Thus, the larger droplets lodge on the foremost filter layers together with some of the smaller droplets and leave some smaller droplets to penetrate with the air stream. As a result, less and less is caught by succeeding filter layers.

TESTS OF RESPIRATORS IN WATER-MIST CARRYING SILICA DUST

Apparatus Used.

The method of testing respirators filtering air containing an aqueous-mist carrying silica dust was similar in principle to the method for paint mist; but the apparatus was modified and the technic was different because it was necessary to count the particles in the air before filtering and in the filtered air. Figure 8 is a diagram of the testing apparatus. The apparatus consists of two similar systems; in Figure 8 the lower system is for determining the silica particles in the original air; the upper system catches the silica particles in the air passed through the respirator or other filter.

The respirator or filter was mounted and placed in a box like that described previously for the tests with paint mist. Air was drawn through the respirator for a 20-minute test period at the rate of 32 liters per minute measured by a flowmeter, and then passed into a Palmer apparatus[8] to catch the dust passing through the respirator. This apparatus is essentially a large pear-shaped glass bulb with a U-tube at the bottom and an S-shaped exit tube for air at the top. About 40 c.c. of dust-free water is placed in the U-tube. When air is drawn through the apparatus it breaks the water into a spray in the bulb which washes out and retains the dust. A supply tube of water was attached, from which water was added to the Palmer apparatus to replace loss by evaporation into the air stream. This apparatus operates best at a rate of air flow of about 127 liters (4½ cubic feet) a minute. As only 32 liters a minute came through the respirator, an auxiliary stream of the purest air obtainable was also passed through the Palmer apparatus at a rate of 95 liters a minute, making a total air flow of 127 liters a minute.

The auxiliary air was taken from the dead end of a tunnel for service pipes in the building, at a point about 60 feet from the nearest tunnel opening, which was a trap-door usually kept closed. The air was filtered through a layer of fabrics closing one side of a tight box. This filter was about 28 by 30 c.m. (11 by 12 inches) in area and was made from outside to inside of 1 ply each of canton flannel, cotton felt, a paper made of cotton fiber, canton flannel, and finally a support of fly screening. Special tests with the Palmer apparatus of the air through this filter showed 3 dust particles per cubic centimeter (3 million per cubic meter), which was regarded as constant and deducted in calculations of efficiencies of the respirators.

All of the air from the Palmer apparatus was drawn into a motor-driven suction pump. The flow rates were controlled by means of three valves or cocks on the connecting tubes, as indicated in Figure 8.

The system for determining the dust in the original air in the box (the lower system in Figure 8) was identical with that described up to and including the Palmer apparatus, except that the filters and their holder were omitted at the inlet end. The inlet was under and about one inch from the respirator filter to assure air of equal dustiness for both systems. The flowmeter and length and diameter of connecting tubes were identical because some dust precipitates on the walls of the tubes, especially after passing through the restriction of the flowmeter where turbulence causes marked precipitation. All of this dust was washed from the tubes after each test and included for determining efficiencies with that caught by the Palmer apparatus.

The lower system was provided further with an electric precipitator tube following its Palmer apparatus. The air was divided by means of a T-tube and stopcock regulator so that 10 liters a minute measured by a flowmeter passed through the precipitator. The precipitator and its electric system were the same as that used in the tests with paint mist; it was operated during a few tests only to determine the amount of dust escaping from the Palmer apparatus and preceding parts, but only the dust caught in the Palmer apparatus and preceding parts was used in calculating efficiencies of the respirators.

Method of Counting Dust Particles.

The water with its suspended dust caught in a Palmer apparatus was transferred to a graduated flask and the apparatus was rinsed with dust-free water and the rinsings added to the flask; all connecting tubes leading to the Palmer apparatus, including the flowmeter head, were washed free of dust and the washings run into the flask; the contents of the flask were then diluted to 500 c.c. in the case of the unfiltered air sample and to 200 c.c., or in some cases 100 c.c., for the sample of dust from the air passed through a filter. The object of different dilutions was to make the two dust suspensions of approximately the same densities for counting later.

A brief outline of the method of determining the numbers of dust particles follows, but for a more complete description the reader may refer to Bulletin 144 of the U. S. Public Health Service[9].

One cubic centimeter of the dust suspension thoroughly mixed was transferred to a Sedgwick-Rafter counting cell 1 mm. deep and allowed to settle for 20 minutes. The particles were then counted through a microscope at 110 diameters magnification, using an eyepiece micrometer with a screen grating that outlined exactly one square millimeter area of field; the particles viewed in the outline represented those originally present in 1 cubic millimeter. The dust particles in one quarter square millimeter were counted, making a total count usually ranging from 70 to 150. In some instances when the filters removed much of the dust the counts were somewhat less. Five counts were made including the center and each corner of the cell and the average was used in calculations. The particles were nearly all less than 5 microns diameter and the particles counted ranged from that size down to the low limit of vision, about ½ to ¼ micron in diameter; most particles were about 1 micron in diameter.

Method of Maintaining Dust Concentrations in Air.

Included with the silica particles were the particles always present in the room air; a special test of room air with a Palmer apparatus showed 16 particles per cubic centimeter. As the dust concentration in the air of the box when spraying was in progress ranged on the average from 160 to 700 particles per c.c., the room dust was not very important. The room dust, however, was unavoidably included with the silica dust desired in the tests.

In some instances when respirators or filters were known to be efficient in restraining dust, the amount delivered by the spray gun was increased to raise the number of particles in the filtered air for counting purposes. The suspensions of dust in water sprayed were always in concentrations of 1 gram of air-floated silica dust (called "Silica Smoke," in the trades) to 100 c.c. of water. The dust suspension was kept evenly suspended in the water by stirring from time to time.

The suspensions used in applying vitreous enamels are of higher concentrations than the 1 per cent just cited. As the spray gun was operated near its minimum delivery for these tests, the low concentration of silica in water was used in order to maintain low concentrations of the dust in the air of the box, according to conditions outlined for the tests, as stated in this paper.

Dust Caught in the Different Parts of the Test Apparatus.

It had been desired to determine the efficiencies of the respirators on the basis of the Palmer apparatus alone. Because dust precipitated unavoidably in some of the parts preceding the Palmer apparatus, a determination of the amount of dust lodging in (1)

[8] Palmer, G. T., A New Sampling Apparatus for the Determination of Aerial Dusts: Amer. Jour. Public Health, vol. 6, 1916, pp. 54-55.
Katz, S. H., Smith, G. W., Myers, W. M., Trostel, L. J., Ingels, M., and Greenburg, L., Comparative Tests of Instruments for Determining Atmospheric Dusts.
[9] U. S. Public Health Service, Bulletin 144, 1925, 69 pp.

the flowmeter and tubes preceding the Palmer apparatus, (2) the electric precipitator following the Palmer apparatus, and (3) the Palmer apparatus, was made in some special tests in order to ascertain the amounts of dust lodging in the aforementioned parts as compared with the Palmer apparatus and the general efficiency of both of these parts. Table 3 gives the result.

TABLE 3

Dust Caught in Palmer Apparatus and Other Parts of Dust-determining Apparatus

Dust caught in	Dust particles per c.c. of air entering	Percentage of total dust caught
Palmer apparatus	524	58
Flowmeter and tubes preceding Palmer apparatus	246	27
Electric precipitator	141	15
Entire apparatus	911	100

The Palmer apparatus caught 524 particles from each cubic centimeter of air passed through, while 141 particles per cubic centimeter failed to lodge in the Palmer apparatus and were carried to the electric precipitator, where they were retained. The electric precipitator retained all dust entering with the air, as judged by the precipitation occurring all in the foremost part of the tube. Based on the numbers of dust particles in the air entering the inlet tube, 58 per cent were caught in the Palmer apparatus, 27 per cent in the flowmeter and tubes preceding the Palmer apparatus, and 15 per cent in the electric precipitator. This special test showed the Palmer apparatus 79 per cent effective in retaining the silica particles in water mist that entered it from the conduits. The efficiencies of the respirators and filters were calculated on the basis of the dust caught in the two Palmer apparatuses and the tubes conducting the dusty air to them, on the assumption that each Palmer apparatus would be fully effective in retaining all the dust precipitated in the conduits preceding them.

Both systems of Palmer apparatus and conduits were considered to have equal percentage efficiencies in retaining the dust passed into them. Provided this is true, the efficiencies of respirators determined by the method employed may be considered as real efficiencies in restraining the silica dust in the water mist.

Filtering Efficiencies of Respirators in Water-Mist Carrying Silica Dust.

Table 4 lists the filtering efficiencies of the different respirators against water-mist carrying silica dust. The table describes the filters in the respirators, states the resistances to air flow before and after testing against silica dust sprayed with water into air for a 20-minute period, states the average dustiness of the air as particles per cubic centimeter, and gives the filtering efficiencies determined.

Increases in resistance were usually negligible because the dust deposited upon a filter was exceedingly small in amount; the maximum increase was 0.15 inch for one of the gas mask canisters. The average dustiness of the air during the tests ranged from 162 particles per cubic centimeter to 487 particles. Filtering efficiencies showed a minimum of 24 per cent for a respirator with a sponge filter and 99.2 per cent for a Fogler flat felt filter.

The efficiencies are usually a little higher than those determined for similar respirators filtering dry silica dust in air[10]. This must be partly due to the effect of droplets of water around some of the particles, which lodge more readily upon the filters and retain their included dust particles, and it may be partly due to the effect of water in causing agglomeration of dust particles included in droplets when the water evaporates, leaving larger particles composed of several adhering small particles floating in the air.

It seems assured that the particles as filtered were mostly dry because a test made with a konimeter[11], failed to show appreciable dust upon a clean glass plate, which was examined microscopically. Had the dust been wet or the air very humid the dust would have precipitated upon the plate together with some moisture. A test with a pretolatum-coated glass plate in the konimeter showed the dust. There were appearances of a few water droplets with a number of dust particles included, or of agglomerated particles, although agglomeration was not determined with certainty. The minute water droplets would last only a very short time in the air before evaporation, because the laboratory air was at about 50 per cent relative humidity, like that of average indoor air in factories in winter, and the amount of water sprayed was very small.

It appears then that unless the spraying is done in a very humid atmosphere, or so much water is sprayed that the air becomes very humid before the droplets of water mist are evaporated, the respirators filter dust particles which have become dry and will be only moderately more efficient in restraining the sprayed silica dust than when the dust is dispersed in air in originally dry condition. If the air in which spraying is done is very humid, higher efficiencies of respirators against sprayed silica dust than those reported herein may be expected. However, tests were not made in humid atmospheres to confirm this. Thus, these tests show efficiencies of respirators under adverse conditions of humidity, which conditions usually predominate, and the protection afforded by respirators worn by sprayers of vitreous enamels will usually correspond to the efficiencies determined.

Filtering Efficiencies of Fabric Filters in Water-Mist Carrying Silica Dust

A series of tests with fabric filters of 100 sq. cm. area and composed of various numbers of plies or layers of filters was made with silica dust sprayed in water, analogous to the tests with paint mist previously described. Table 5 lists the results; the filtering efficiencies of the various filters with increasing numbers of plies of fabric are presented graphically in Figure 6. The muslin and filter papers were identical with those reported in Table 2; the other materials in Table 5 were purchased as nearly like those in Table 2 as were available at the time but they were not identical.

The efficiencies of fabric filters in increasing numbers of plies filtering silica dust with water-mist in air are similar to those found with paint mist, as indicated by the curves in Figure 9 when compared to those in Figure 7. Instead of straight lines generally found when testing filters against dry silica dust of uniformly sized particles dispersed in air[12], the graphs are curved through the range of small numbers of plies, then tend to straight lines. As with the paint mist, the curves must be due to more dust proportionally being caught on the first filters because of the inclusion of agglomerates and dust particles held in water droplets. When the large, easily removed particles are eliminated, the individual particles of nearly uniform size tend toward a straight line upon the logarithmic chart.

On the whole, the filters are less efficient against silica dust spray than against the lead paint spray, but are more efficient than similar filters against silica dust dispersed into air in a dry state[13]. The dense filters give very high efficiencies; 4 plies of high-grade chemical filter paper restrained 99.7 per cent of the dust; the loose texture cheese cloth shows lowest filtering efficiency, but even this material built into a layer of sufficient thickness can produce very efficient filters[14], although they may be impracticable because of their thickness.

DISCUSSION AND CONCLUSIONS

The questions concerning paint spray proposed when this investigation was undertaken were the following:

1. What filtering material, if any, is adequate—
   (a) To reduce the lead content of the air to which a spray coater is exposed from 200 milligrams per cubic meter to 0.6 milligram per cubic meter?
   (b) To reduce the amount of benzol under similar conditions from 2000 to 75 parts per million?
2. How long would such a layer function?
3. How do certain typical masks now available measure up to these standards?

The answers numbered to correspond to the questions are:

Material Adequate for Filtering Paint Spray and Benzol.

1—(a). Only one filter material (tested as such without respirator setting) equaled the specification during the tests conducted; that is, 3 plies of high-grade chemical filter paper. The figures of question 1—(a) state an efficiency of 99.7 on a percentage

[10] See reference 1.
[11] See reference 9
[12] See reference 1
[13] See reference 1.
[14] See reference 1.

TABLE 4

Efficiencies of Respirators Filtering Silica Dust in Water-Mist from Spray Gun. Rate of Air Flow, 32 Liters per Minute; Period of Testing, 20 Minutes

Test No.	Number of respirator	Filter material	Resistance to air flow at 85 liters per minute, inches of water		Aver. amount of dust in air, particles per c. c.[1]	Filtering efficiency of respirator, based on numbers of Particles, per cent	Remarks
			Start	End			
892	1	Sponge	0.25	0.20	190	24	Sponge was wet before test.
888	2	Cotton paper	.70	.75	399	59	1 ply paper.
889	2	Cotton paper	.65	.70	393	62	1 ply paper.
890	2	Cotton paper	.60	.65	421	61	1 ply paper.
885	3	Cotton paper	.30	.35	309	55	1 ply paper in filter.
886	3	Cotton paper	.35	.35	334	57	1 ply paper in filter.
887	3	Cotton paper	.55	.60	265	73	2 plies of paper in filter.
896	4	Gauzy tissue	.35	.35	318	45	4 plies of paper.
897	4	Gauzy tissue	.55	.60	487	66	4 plies of paper.
981	5	Cotton flannel	.20	.20	434	62	2 plies flannel.
5001	9	Canton flannel	1.70	1.70	509	80	2 plies flannel built into a cap. This respirator had been used considerably; it was freed of dust before testing by means of compressed air.
5003	9	Canton flannel	1.45	1.45	546	90	3 plies flannel built into a cap. This respirator was new and unused.
893	6	Silk gauze and cheesecloth	.10	.10	205	46	1 ply silk, 3 plies cheesecloth.
898	6	Silk gauze and cheesecloth	.05	.05	405	37	1 ply silk, 2 plies cheesecloth.
899	2A	Cotton felt	.10	.10	343	72	
900	7	Cotton wool	.15	.15	162	59	Cotton between cheesecloth; 109 sq. cm. of filter was exposed.
894	10	Cotton wool	3.40	3.55	415	95	Canister contains 2 cotton filters, 1 of toweling and 600 c.c. charcoal.
895	10	Cotton wool	3.50	3.55	321	96	Canister contains 2 cotton filters, 1 of toweling and 600 c.c. charcoal.
5002	12	Dense wool felt				99.2	

[1] For particles per cubic meter, multiply by 1,000,000.

TABLE 5

Efficiencies of Various Fabrics Filtering Silica Dust in Water-Mist from Spray Gun. Filter Area, 100 Square Centimeters; Rate of Air Flow, 32 Liters per Minute; Period of Testing, 20 Minutes

Test No.	Fabric	No. of plies	Resistance to air flow, inches of water		Average amount of dust in air, particles per cc.	Filtering efficiency of respirators based on numbes of particles, per cent
			Start	End		
877	Cheesecloth, 27 by 30 threads per inch, 36.0 grams per square yard	2	0.00	0.00	571	15
878	Cheesecloth, 27 by 30 threads per inch, 36.0 grams per square yard	4	.02	.02	299	35
879	Cheesecloth, 27 by 30 threads per inch, 36.0 grams per square yard	8	.03	.03	368	44
880	Cheesecloth, 27 by 30 threads per inch, 36.0 grams per square yard	16	.04	.04	371	58
881	Cheesecloth, 27 by 30 threads per inch, 36.0 grams per square yard	32	.07	.07	168	62
871	Muslin, 66 by 66 threads per inch, 130 g. per square yard	1	.10	.10	314	44
872	Muslin, 66 by 66 threads per inch, 130 g. per square yard	2	.20	.20	408	58
873	Muslin, 66 by 66 threads per inch, 130 g. per square yard	4	.40	.40	296	71
874	Muslin, 66 by 66 threads per inch, 130 g. per square yard	8	.80	.80	367	81
875	Muslin, 66 by 66 threads per inch .130 g. per square yard	16	2.00	2.05	337	92
867	Muslin (bleached), 68 by 76 threads per inch, 90 g. per square yard	1	.85	1.40	219	69
868	Muslin (bleached), 68 by 76 threads per inch, 90 g. per square yard	2	1.25	1.65	271	84
869	Muslin (bleached), 68 by 76 threads per inch, 90 g. per square yard	4	4.20	5.40	284	95
870	Muslin (bleached), 68 by 76 threads per inch, 90 g per square yard	8	6.85	7.55	321	97.4
871	Muslin (bleached), 68 by 76 threads per inch, 90 g. per square yard	16	17.45	18.40	768	99.6
853	Canton flannel, 44 by 76 threads per inch, 159 g. per square yard	1	.10	.13	306	51
854	Canton flannel, 44 by 76 threads per inch, 159 g. per square yard	2	.25	.30	569	62
855	Canton flannel, 44 by 76 threads per inch, 159 g. per square yard	4	.45	.50	94	77
857	Canton flannel, 44 by 76 threads per inch, 159 g. per square yard	8	1.35	1.35	212	85
858	Canton flannel, 44 by 76 threads per inch, 159 g. per square yard	16	3.10	3.10	304	93
856	Cotton felt, 90 g. per square yard, thickness 0.69 mm.	1	.05	.10	341	44
859	Cotton felt, 90 g. per square yard, thickness 0.69 mm.	2	.10	.10	315	51
860	Cotton felt, 90 g. per square yard, thickness 0.69 mm.	4	.15	.15	321	58
861	Cotton felt, 90 g. per square yard, thickness 0.69 mm.	8	.35	.35	137	74
862	Cotton felt, 90 g. per square yard, thickness 0.69 mm.	16	1.15	1.15	390	88
863	Filter paper, S. & S. No. 589, black label	1	2.25	3.15	337	97.9
864	Filter paper, S. & S. No. 589, black label	2	4.15	5.15	387	98.2
866	Filter paper, S. & S. No. 589, black label	3	6.55	7.35	512	98.9
865	Filter paper, S. & S. No. 589, black label	4	10.15	11.05	521	99.7
882	Absorbent cotton between cheesecloths, 403 g. per square yard	1	.20	.20	280	74
883	Absorbent cotton between cheesecloths, 403 g. per square yard	2	.60	.60	402	89
884	Absorbent cotton between cheesecloths, 403 g. per square yard	4	1.85	1.85	324	97.9

basis. Several filters tested close to this. The following gave 99 per cent or more: muslin, 12 and 16 plies; canton flannel, 8 plies; absorbent cotton, 3 and 4 plies; and filter paper, 2 and 3 plies; 6 plies of a cotton felt tested 98.5 per cent efficiency. Had sufficient time been available the tests would have been extended. Under the circumstances it appears permissible to extrapolate the average curves, the short extent remaining to the efficiency of 99.7 per cent in order to estimate the number of plies of the different filters producing that efficiency. The extrapolations are shown by dotted lines in Figure 7; they indicate that 99.7 per cent efficiency may be developed by filters of the absorbent cotton in 5 plies, canton flannel in 13 plies, felt in 16 plies, and muslin in (probably) 30 plies. The necessary cheesecloth cannot be estimated from the insufficient data available, but a large and probably impracticable number of plies would be necessary.

1—(b). Activated charcoal filters can reduce the amount of benzol in air from 2000 to 75 parts per million or less. A sufficient quantity must be provided; 60 c.c. of the charcoal was found adequate for a period of 19 minutes; under test conditions 600 c.c. lasted 250 minutes. Under conditions prevailing in painting practice considerably longer life may usually be expected.

Filtering Efficiency and Resistance Due to Paint.

2. Filters for restraining paint mist will function continuously without decrease in efficiency and as long as the resistance to air flow remains tolerable. In general, filtering efficiency tends to increase rather than decrease as deposits gather upon filters; but resistance increases at the same time. Gas masks of the army type may be worn when the resistance does not exceed 4 inches of water. However, the amount of work the wearer can do is reduced, unless the work does not require much physical exertion. The capacity of a man for hard work while wearing a gas mask (army type) is only one-half that without the mask. Respirators with resistances not exceeding 2 inches of water may be worn indefinitely without breathing distress during hard work. With these criteria it may be stated that the filters will function until resistance to breathing through clogging with deposited paint becomes excessive, which should be a period of hours or even a working day for all the filters tested, excepting possibly the chemical filter paper and the muslin in 16 plies. Only one ply of the chemical filter paper, with resistance of 2.5 inches, could be tolerated at all in a respirator (three plies were needed to test as much as 99.7 per cent efficient); 16 plies of muslin filter have a resistance of 2.2 inches of water; when fresh, both of these might be used in respirators by paint sprayers for probably an hour or two before clogging necessitates change.

Efficiency of Certain Masks in Paint Spray.

3. Only the army type gas mask No. 10 and the No. 8 respirator with cartridge filter tested 99.7 per cent efficient against the lead in paint spray. Also, these are the only two which meet the specifications for benzol, lasting respectively 250 and 19 minutes; the others have no capacity for benzol. In filtering the lead the No. 6 respirator with filter of one ply silk gauze and 3 plies of cheesecloth was 74 per cent efficient. A sponge filter respirator was 84 per cent efficient. All of the others were 94 per cent or more.

In actual service, army-type gas masks worn by spray painters have been known by the authors to last 2 weeks or more before needing a change of canister. All of the industrial respirators would probably serve for a day or longer.

Among the questions concerning vitreous enamel spray proposed when this investigation was undertaken were the following:

1. What filtering material, if any, is adequate to reduce the number of silica dust particles under spray-coating conditions from 200,000,000 per cubic meter to 100,000, as determined by the Palmer method?

2. How long would such a layer function?

3. How do certain typical masks now available measure up to this standard?

The answers corresponding are:

Material for Filtering Silica Dust Spray.

1. No practical filter was found capable of reducing the silica particles from 200,000,000 per cubic meter to 100,000. This represents a filtering efficiency of 99.95 per cent and the highest efficiency attained was 99.7 per cent for a filter of 100 square centimeters area composed of 4 layers of a chemical filter paper of high quality. This filter, however, had a resistance of 10 to 11 inches of water to air flowing at the rate of 85 liters per minute, which is much too high for use in a respirator. If a resistance of 3 inches of water is taken as a maximum to be tolerated in a dust respirator, the efficiencies given by filters included thereto were as follows:

Material and plies	Resistance inches of water	Efficiency, per cent
Cheesecloth, 32	0.07	62.
Muslin, 16	2.0	92.
Muslin, bleached and closely woven, 2	1.25	84.
Canton flannel, 16	3.1	93.
Cotton felt, 16	1.2	88.
Chemical filter-paper, 1	2.3	97.9
Absorbent cotton (403 grams per sq. yd.)	1.9	97.9

A filtering efficiency of 90 per cent under the conditions thus appears to be excellent for filters of tolerable resistance, although a few filters can exceed 90 per cent.

Filtering Efficiency and Resistance due to Silica Dust.

2. The filters just mentioned would probably function throughout a working day of 8 hours if used in respirators by spray-coaters applying vitreous enamels, except in the case of the filter paper. During 20-minute periods of testing no noticeable increase in resistance occurred in the fabrics; a filter paper increased 0.9-inch of water through clogging with dust. As resistance determines the period of usefulness of a filter, rather than filtering efficiency which increases with use, a paper of the type tested could be used probably about an hour, until resistance increase would necessitate changing to a fresh filter. For this reason the fabric filters appear more practicable.

Efficiency of Certain Masks in Silica-Dust Spray.

3. No respirator equaled the specifications stated for filtering efficiency; the most efficient respirator was the gas mask type equipped with a Fogler flat felt filter which gave 99.2 per cent. Next came the gas mask with a canister holding two filters of cotton wool; it was 95 per cent efficient. A Bureau of Mines cap type of respirator was 80 per cent efficient. Commercial respirators of the pig-snout type ranged in efficiency from 24 per cent for one with a sponge filter to 73 per cent for a respirator with two plies of a cotton paper filter. The pig-snout respirators are not all very efficient in restraining very fine silica dust under spray-coating conditions; the better ones can restrain about half or a little more of the dust in air as breathed and so can be of real benefit. The Fogler flat-felt filter is much superior as a filter and it should be preferred under very hazardous dust conditions.

The foregoing conclusions are derived only from laboratory tests with chemical apparatus. They are believed to be correct for present-day respirators free from leakage, used under spray-coating conditions as outlined. Their application must, however, be confirmed by further observation in actual use.

SUMMARY OF THE

Minority Report on Report of Spray Coating Committee

While we are in accord with many statements in the report of your Committee on Spray Coating, particularly as to the hazards in the use of benzol, there are other statements and conclusions expressed therein, of a fundamental nature, which we feel are not well founded and, in some cases, are diametrically opposed to the data placed before your committee. Our dissent from that report is explained in detail below, as follows:

1st—The detailed facts of the Committee's study were not placed before the members until after discussion at the last meeting and just before voting on the adoption of the report. This data constituted such a mass of figures, there was no opportunity afforded the Committee to study such details, nor do we understand that such data was in shape for consideration. Only the summary of Dr. Smyth's investigation was in the hands of the members, and, as this shows the results by plants or groups of subjects and not by each individual, booth, person, or the material used separately, the inaccuracy of the conclusions derived from such information obviously is open to question.

We feel that the data made available to the committee, perhaps due to the combined manner of setting it forth, is inconsistent, inaccurate and fails to justify some of the conclusions expressed by the Committee on some very important phases of the subject.

2nd—That your Spray Coating Committee's report, by its references to so-called historical literature, experiments with obsolete equipment, out of date investigations, meagre and incomplete data on studies of antiquity, not demanded by literary style or a proper bibliographical treatise of such a subject, seriously impairs its effectiveness. We deem such statements are irrelevant to a study seeking to find existing hazards, if any, and to recommend reasonable correctives.

3rd—By improper construction of this summarized data, and not the basic detail facts of the study, and by the exclusion of late statistical data published by the Federal Government relating to lead poisoning cases or deaths in the United States, we feel this report, without warrant, seeks to unduly exaggerate the so-called hazards of the spray process, particularly as to the use of lead. In thus creating a phantom of fictional perils, not corroborated, we believe, by the limited facts available to the Committee, we believe it will tend to promote the disregard of its recommendations instead of furthering their acceptance as a wholesome medium for enhancing health protection among the industries of the country, who may, in some minor or greater degree employ such products in their finishing operations.

4th—By refusing to clearly differentiate building or structural painting (exterior and interior) from industrial or manufacturing finishing processes, involving vastly dissimilar facts, working conditions, type of equipment, and, in a measure, the materials used, we feel that its conclusions are misleading and fundamentally wrong. Such statements as "spray painters," "interior painting" and "indoor painting" unwarrantedly convey the impression that the conditions in the industrial finishing field are applicable to the building and structural field. We think these classes should be segregated and treated separately and the report clarified.

5th—That its treatment of state regulatory conditions is incomplete and improper and omits pertinent and published facts, for instance the Massachusetts investigation and regulations, yet unduly stresses the Wisconsin regulations.

6th—That its conclusions and recommendations as to respirators are erroneous, unduly preferential to a certain type of respirators, prejudices research and future development along this line, and are contrary to the facts and data embodied in the report of its Subcommittee on Tests of Painters' Respirators.

7th—That its conclusions and recommendations of frequent, periodical, medical examination of spray painters or finishers "employed within buildings, booths or *other indoor or enclosed spaces* in spray coating" are not supported by the facts of this study submitted to the committee in so far as building or structural spray painting is concerned.

8th—That its conclusions and recommendations calling for an air velocity of not less than "200 linear feet per minute" is wholly unwarranted by the facts submitted. The recognized standard of equipment manufacturers, based on extensive engineering experience, is 100 linear feet per minute. It is claimed that the study showed an average air velocity for all practical purposes to be 60 linear feet, and we recommended "an average *minimum* of 90 linear feet per minute or 50 per cent more than that found by the study and within 10 per cent of the standard of reputable equipment manufacturers. Considerable speculation is indulged in by this Committee throughout the report as to the proper air velocity requisite for reasonable protection and extreme or erroneous citations of the data submitted to the committee to support it. Stress is laid upon the tentative proposal of 125 linear feet in the pending Pennsylvania proceedings, but as the underlying data in that investigation has not been made public and a counter-proposal of a minimum of 90 linear feet per minute has been submitted, it is our belief that the conclusion of the Committee that not less than 200 linear feet per minute is absurd in the light of the facts of this study. No tests were made to determine the relation of air velocity to air contamination in the spraying of lead paints, as was done in the case of benzol lacquers, and the conclusion of the committee as to air velocity with respect to lead paints seems only a guess.

The Michigan Department of Labor and Industry, in their recent investigation of the spray process in the industrial plants of that state, prescribed *"an average minimum air velocity of 90 linear feet per minute"* at the working face of the spray booth. No state authority that has investigated the matter has prescribed a definite air velocity. We feel your Committee has grievously erred in its conclusions and recommendations on this important phase, and that in the interest of all concerned this report should be modified by the National Safety Council to accord with the facts.

WILLIAM J. PITT.
WAYNE B. THOMPSON.